VISUOSPATIAL AND VISUOMOTOR PERFORMANCE IN NORMAL AND DISABLED CHILDREN

By

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This dissertation is dedicated to my parents, Carolyn M. Pickard and Ellis J. Oglesby, Jr., and to my brother, Ellis J. Oglesby, III. Their love and consistent support has been an integral part of my entire life. In particular, this dedication is to my parents, for teaching me to have confidence in myself and to pursue my dreams, and to my brother, for his heart of gold and for reminding me by his example to always remain true to my own values.

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Abstract of Dissertation Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

VISUOSPATIAL AND VISUOMOTOR PERFORMANCE IN NORMAL AND DISABLED CHILDREN

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Visuoperceptual ability and visuomotor skill in early and middle childhood provide the foundations for more complex cognitive functions as children grow older. The evaluation of visuoperceptual and visuomotor performance is therefore particularly important in the neuropsychological assessment of children. However, necessity has forced many pediatric neuropsychologists to employ adult assessment instruments in their work with children despite somewhat limited normative and psychometric information. Recent research exploring the use of such measures in children has supported the use of the Hooper Visual Organization Test (HVOT) and the Rey-Osterrieth Complex Figure Test (ROCFT). This project investigated developmental trends, construct validity, and differences between normal and disabled children's performance on the HVOT and the ROCFT in children.

The HVOT and the ROCFT, along with several other tests of general, visuoperceptual, or visuomotor ability, were administered to 25 normal control children between the ages of 6 and 11. In addition, archival data were obtained from the files of 43 neurologically impaired children and 32 learning disabled children aged 6-11 years.

Consistent with prior research, older children's performances on the HVOT and the ROCFT were significantly better than younger children's performances. Promising preliminary support for the construct validity of the HVOT and the ROCFT emerged in the form of several high correlations between the HVOT and the ROCFT and other measures of visuospatial, constructional, and visuomotor ability. Finally, the ROCFT demonstrated some usefulness in discriminating between neurologically impaired children and normal or learning disabled children.

Thus, the HVOT and the ROCFT have the potential to provide valuable information in the assessment of visuospatial and visuomotor skills in children. Both the HVOT and the ROCFT are sensitive to developmental changes in middle childhood (6 through 11 years). Current evidence provides promising preliminary support for their construct validity as tests of visuospatial, constructional, and visuomotor abilities. Although neither the HVOT nor the ROCFT revealed differences between the normal and learning disabled samples, the ROCFT was significantly worse in neurologically impaired children and therefore has particular potential as

a tool in the assessment of neurologically impaired children.

CHAPTER 1
REVIEW OF THE LITERATURE

Introduction

Child neuropsychology, like adult neuropsychology, relies on assessment instruments to measure the existence and extent of neurological dysfunction. However, because child neuropsychology is a relatively new field, the usefulness of a number of instruments used with children has not been extensively evaluated empirically. Indeed, a number of adult neuropsychological tests have begun to be employed for evaluation of children despite relatively little information about the instruments' value in assessments of children.

Visuomotor Skills in Human Development

Williams (1983) has pointed out that perceptual and perceptual-motor tasks are particularly important in childhood. Although perceptual and perceptual-motor skills for older children and adults are not particularly correlated with intelligence, studies with young children (e.g., five year olds) display significant associations with intelligence (Williams, 1983). Indeed, the ability to perceive accurately and to interact with the environment effectively has been identified as a virtual prerequisite for cognitive development and academic achievement (Melamed

& Melamed, 1985; Williams, 1983). Therefore, evaluating deficits in perception and in perceptual-motor tasks is an important component of neuropsychological assessment of children (Melamed & Melamed, 1985). Because humans rely so heavily on vision to interpret environmental stimuli, visual perception is of particular interest and importance.

Piaget's (1927/1977; 1936/1977; 1937/1977; Piaget & Inhelder, 1969) theory provides a theoretical framework for understanding the importance of visuomotor skills in human development. Piaget proposed that the first year and a half of life is a sensorimotor period, in which the child develops greater awareness of his or her environment and becomes increasingly aware of how he/she can affect that environment. Development of visual perception and of motor activity is key to this stage. The dawning awareness of the "laws of nature" and of how he/she can influence the environment is a prerequisite for the child to enter the preoperational or symbolic stage, which lasts from 18 months to 7 years of age, and in which the child begins to be able to think and act symbolically. The child must have an awareness of concrete information about the environment, derived through visuomotor activity, and his or her role in it before he/she can begin to represent that environment symbolically. The symbolic activity of this stage is necessary for the child to attain the next stage, formal operations (ages 7 to 11), in which he/she begins to be able to reason logically about concrete situations. Finally,

this logical reasoning is expanded to abstract situations, and the child has attained formal operations. It is clear from Piaget's theoretical model that visuomotor activity, particularly of the sensorimotor and preoperational periods, is crucial to the development of cognitive functioning (Piaget, 1927/1977; 1936/1977; 1937/1977; Piaget & Inhelder, 1969).

With this theoretical model of the importance of visuomotor skills in mind, children's development of visuomotor skills will be explored. First, however, it is important to understand what neuroanatomical areas are involved in visuomotor tasks.

Neuroanatomy of Visual Perception

The Retina, Optic Nerve, Optic Chiasm, and Optic Tract

Visual perception begins in the retina, where the primary receptors are rods (for vision in low intensity light) and cones (for color vision and vision in high intensity light). The highest proportion of cones is found in the area of central vision, particularly the fovea centralis. Bipolar cells, the primary afferent neurons of the visual system, receive input from rods and cones as well as from horizontal and amacrine cells. The bipolar cells terminate on the ganglion cells which form the optic nerve (Carpenter, 1991; Kandel, Schwartz, & Jessell, 1991; Nieuwenhuys, Voogd, & van Huijzen, 1988; Spreen, Tupper, Risser, Tuokko, & Edgell, 1984).

The optic nerve, the pathway for virtually all of the fibers originating in the retina, moves posteriorly and somewhat medially from the eyes before it decussates in the optic chiasm: the nasal half of the retinal image of each eye crosses to the other hemisphere (Figure 1). Thus, after passing through the optic chiasm, visual information from the right field of vision is processed in the left hemisphere of the brain, and vice versa. After the decussation of the optic nerve at the optic chiasm, the ganglion cells form the optic tract. The optic tract runs posteriorly and laterally (around the hypothalamus and thalamus) before terminating in the lateral geniculate body of the thalamus (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988; Spreen et al., 1984).

Systems of Visual Processing Other than the Geniculostriate System

Before turning to the geniculostriate system, the system responsible for most visual processing, visual systems responsible for functions such as visual attention, visual orientation, and control of nonvoluntary eye movements will be reviewed. One such system, which provides input to assist in regulation of circadian rhythm, consists of retinohypothalamic fibers which project directly from the retina to the suprachiasmatic nucleus of the hypothalamus. Another system, the extrageniculate pathway, consists of fibers, called the brachium of the superior colliculus, which proceed directly through the lateral geniculate body

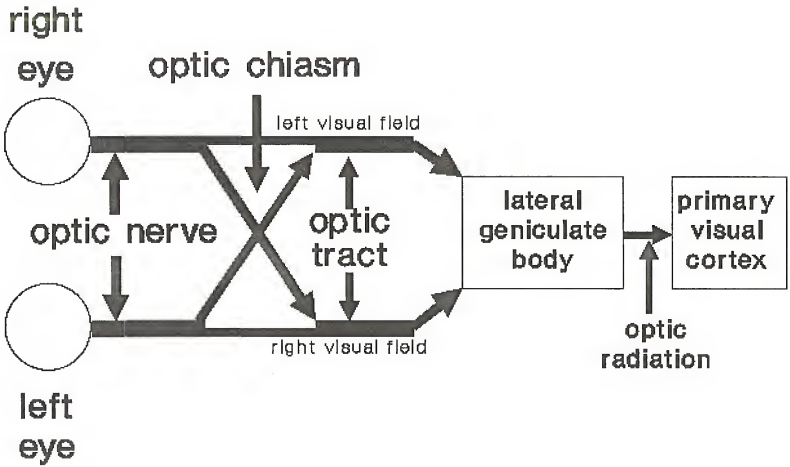

Figure 1. The Optic Nerve, Chiasm, and Tract

to the superior colliculus and pretectal area, which send efferent fibers to the pulvinar. The pretectal area also transmits to the bilateral accessory oculomotor nuclei, which send efferent fibers to the ciliary ganglia which constrict the pupil in response to light. A complex system involving multiple cortical and subcortical areas controls orienting responses, tracking, and other eye movements via input to the abducens and oculomotor nerves. Areas with direct or indirect input into this system include the superior colliculus, pretectal region, vestibular nuclei, the ventral nucleus of the thalamus, the visual cortex (primary and association areas), motor cortex, frontal eye fields, auditory cortex, the pars reticulata of the substantia nigra, and the paramedian pontine reticular formation. Finally, the accessory optic system consists of reciprocal fibers between the optic tract and the dorsal, lateral, and medial nuclei of the accessory optic system, which is located in the mesencephalon. Fibers from these nuclei transmit to the cerebellum via the inferior olive, and are involved in visual-vestibular interaction (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988).

The Geniculostriate System

The lateral geniculate body

Most processing of visual stimuli occurs through the geniculostriate system, which originates in the lateral

geniculate body. The lateral geniculate body of the thalamus has six layers: three (layers 2, 3, and 5) for the ipsilateral eye and three (layers 1, 4, and 6) for the contralateral eye. Layers 1 and 2 are magnocellular, while layers 3 through 6 are parvocellular (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988).

Each retinal area involved in perception of the contralateral visual field corresponds to a particular location in the lateral geniculate body. Information from the lower visual field is located medially in the lateral geniculate nucleus, and information from the upper visual field is located laterally. The macula, or area for central vision, is represented caudally in the lateral geniculate nucleus, while peripheral visual information is represented laterally and rostrally (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988).

Primary visual cortex

From the lateral geniculate nucleus, neurons project via the retrolenticular portion of the internal capsule to form the optic radiation (Figure 2). Most of the optic radiation terminates in primary visual cortex (Brodmann's area 17), located in the occipital lobe along the calcarine fissure, and remaining fibers terminate in secondary and tertiary visual cortex (Brodmann's areas 17 and 18). Most fibers of the optic radiation terminate in layer IV. Macular information is processed at the occipital pole, the most caudal part of primary visual cortex, while peripheral

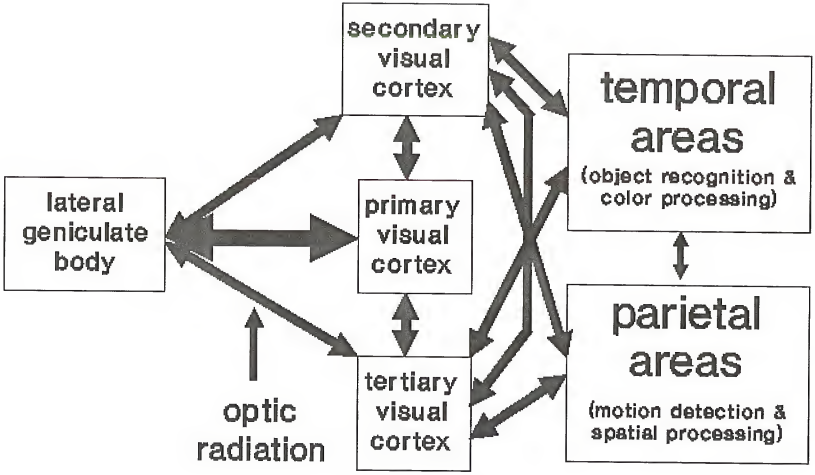

Figure 2. The Geniculostriate Visual System

information is processed in rostral areas of primary visual cortex. The lower visual field is represented superior to the calcarine fissure, with the upper visual field represented inferior to the calcarine fissure (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988; Spreen et al., 1984).

Cells in the primary visual cortex are more selective in their responsiveness than retinal ganglion cells and lateral geniculate body cells. Certain cells respond only to thin rectangles of light, others to dark bars, others to edges. In addition to type of stimuli, primary visual cortex cells respond selectively to the orientation of stimuli (Carpenter, 1991; Hubel & Wiesel, 1962; Kandel et al., 1991).

Orientation columns

Cells with particular orientation biases form orientation columns in the primary visual cortex. Orientation columns consist of simple cells in layer IV and complex cells in layers above and below layer IV. Simple cells receive monocular input, and respond selectively to stimuli of a particular type and orientation. Complex cells receive binocular input from multiple simple cells, and respond selectively to stimuli that move in a particular direction. Interspersed in layers II and III of the orientation columns are "blobs," which are not selective to orientation, and which are involved in color vision

(Carpenter, 1991; Hubel & Wiesel, 1962; Kandel et al., 1991; Nieuwenhuys et al., 1988).

Ocular dominance columns

In addition to ocular orientation columns, primary visual cortex is organized in ocular dominance columns. Each ocular dominance column responds primarily to input from one eye (cells receiving monocular input react solely to stimuli from that eye, while cells receiving binocular input react preferentially to stimuli from that eye). The ocular dominance columns alternate between left and right dominance, so that adjacent columns have the opposite dominance. These ocular dominance columns are involved in combining the retinal images projected to each eye and are necessary to depth perception. The only two regions of primary visual cortex without ocular dominance columns are those areas representing the "blind spot" in vision and those areas which represent vision which is so peripheral that it can only be perceived by the nasal portion of one retina (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988).

The ocular orientation columns and ocular dominance columns form hypercolumns, which are a set of columns which respond to stimuli in a particular small region of the visual field. Such hypercolumns consist of two ocular dominance columns (one per eye), and two full sets of orientation columns (one set per ocular dominance column) (Kandel et al., 1991).

Secondary and tertiary visual cortex

The secondary visual cortex (Brodmann's area 18) surrounds the primary visual cortex and, along with tertiary visual cortex (Brodmann's area 19), receives input from area 17 as well as direct input from the lateral geniculate body and pulvinar. In addition, multiple commissural fibers connect corresponding areas of visual cortex, resulting in bilateral rather than contralateral representation of stimuli. As in the primary visual cortex, cells in secondary visual cortex respond to particular stimuli in a specific orientation. However, cells in secondary and tertiary visual cortex are mostly complex and hypercomplex (Carpenter, 1991).

The magnocellular system

In addition to the classifications according to columns, layers, and neuroanatomical location, the visual processes can also be classified according to function and the type of cellular input they receive from the lateral geniculate body. Kandel et al. (1991) identify three systems: the magnocellular system, parvocellular-interblob system, and the parvocellular-blob system.

The magnocellular system, involved primarily in motion detection but also with spatial information and depth perception, projects from the magnocellular layers of the lateral geniculate body to layers IV and VI in the primary visual cortex. From area 17, the magnocellular system proceeds to the thick stripe of secondary visual cortex as

well as to tertiary visual cortex and to the middle temporal area, which is concerned with depth and motion perception. The magnocellular system terminates in the ventral intraparietal region, the medial superior temporal region, and the posterior parietal region (involved in spatial organization) (Haxby et al., 1991; Kandel et al., 1991; Tranel, 1992). Consistent with the magnocellular system's termination in parietal regions, McIntosh, Grady, Ungerleider, Haxby, Rapoport, and Horwitz's (1994) positron emission tomography results indicated that spatial tasks localized to right occipitoparietal regions.

The parvocellular-interblob system

The parvocellular-interblob system (interblobs separate blobs), involved in form perception and somewhat involved in color perception, proceeds from the parvocellular layers in the lateral geniculate body to the interblobs in layers II and III of primary visual cortex. From primary visual cortex, these cells project to the pale interstripe of secondary visual cortex and then to tertiary visual cortex. The parvocellular-interblob system terminates primarily in the inferotemporal region (important for recognition of form) and also projects to the posterior parietal lobe (Kandel et al., 1991). The termination in the inferotemporal region for this system is consistent with recent results using positron emission tomography which indicate that object identification localizes to occipitotemporal regions (McIntosh et al., 1994).

The parvocellular-blob system

The parvocellular-blob system, involved in color vision, progresses from the parvocellular layer of the lateral geniculate body to the blobs in layers II and III of primary visual cortex. The blobs in primary visual cortex project to the thin stripe of secondary visual cortex, which in turn transmits to tertiary visual cortex. The parvocellular-blob system terminates in the inferotemporal region.

Other efferent projections of the visual cortex

In addition to the above-described projections to parietal and temporal cortex, visual cortex efferents project to the lateral geniculate body, the pulvinar, the thalamic reticularis nucleus, the pretectal area, and the superior colliculus (Haxby et al., 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988; Tranel, 1992; Williams, 1983).

The importance of the processing in parietal and temporal regions, which receive associations from the visual cortex, cannot be underestimated. In monkeys, disconnection of visual cortex from such areas of the brain results in apparent blindness, although the visual cortex displays normal activation patterns (Nakamura & Mishkin, 1986; Nakamura, Schein, & Desimone, 1986).

Neuroanatomy of Voluntary Motor Activity

Perception is only the first step in perceptual-motor tasks. The neuroanatomical aspects of the motor component of perceptual-motor skills will next be presented. The major cortical areas for initiating and controlling voluntary motor activity include primary motor cortex (Brodmann's area 4), premotor cortex (lateral Brodmann's area 6), and supplementary motor cortex (medial Brodmann's area 6) (Figure 3).

The Primary Motor Area

The primary motor cortex, located in the posterior precentral gyrus, is called agranular cortex because of increased pyramidal cells in layer III and in layer V (where the giant cells of Betz are located), thereby obscuring the internal granular layer. The primary motor cortex represents contralateral body parts sequentially, beginning with the pharynx in the most inferior portion of the precentral gyrus, and proceeding dorsally through the tongue, face, fingers, arm, and knee, with the ankle and toes represented at the medial inferior edge of the hemisphere (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988; Snell, 1992).

The primary motor cortex receives afferent fibers from the ventral lateral and ventral posterior lateral nuclei of the thalamus (these nuclei receive and thus probably relay projections from the cerebellum, globus pallidus, and

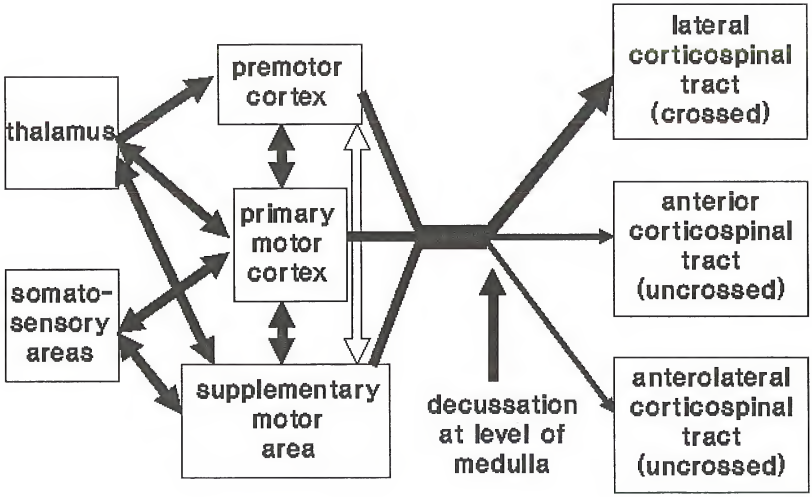

Figure 3. Motor Areas and the Corticospinal Tracts

substantia nigra), the primary somatosensory area, somatosensory association areas, premotor cortex, and the supplementary motor area. This set of input is consistent with the primary motor area's role of initiating and controlling voluntary movement. Primary motor cortex's projections, primarily from layer V, form part of the corticospinal tract. Other efferent projections transmit to somatosensory cortex, the supplementary motor area, the ventral lateral and ventral posterior lateral nuclei of the thalamus, and the striatum. Ablations of the primary motor cortex in monkeys result in short-term contralateral paralysis, hypotonia, and areflexia, and long-term impairment of skilled movement (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988; Spreen et al., 1984).

The Premotor Area

Located anterior to the primary motor area, the premotor area is agranular, but giant cells of Betz are absent. The premotor area receives afferent projections primarily from the posterior parietal cortex, but also from the supplementary motor area and the ventral lateral nucleus of the thalamus (which receives input from the globus pallidus, substantia nigra, and the cerebellum). Like the primary motor cortex, the premotor area forms part of the corticospinal tract; in addition, the premotor area projects to brain stem nuclei that are involved in medial descending systems (particularly the reticulospinal system). The

premotor area seems to be involved in muscle control and in spatial preparations for movement (e.g., orienting to a target) (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988).

The Supplementary Motor Area

The supplementary motor area, located on the medial superior frontal gyrus, receives afferent fibers from primary motor cortex, premotor cortex, somatosensory cortex, the contralateral supplementary motor area, and the ventral lateral nucleus of the thalamus (which receives input from the cerebellum, globus pallidus, and substantia nigra). The supplementary motor area projects to the primary motor area, premotor area, somatosensory cortex, contralateral supplemental motor area, caudate nucleus, putamen, the corticospinal tract, and the ventral anterior and medial dorsal nuclei of the thalamus. Lesions in the supplementary motor area result in akinesia and poverty of spontaneous speech. The supplementary motor area is involved in carrying out programmed movement, planning movement, and coordinating on-going complex movement (Carpenter, 1991; Kandel et al., 1991).

The Corticospinal Tracts

Voluntary movements of the body and limbs are transmitted from the brain via the spinal cord, in spinal cord tracts called the corticospinal tract, the rubrospinal

tract, and the reticulospinal tracts. Other spinal tracts (tectospinal and vestibulospinal) are not directly involved in voluntary movement: the tectospinal tract is involved in reactive postural movements, and the vestibulospinal tract pertains to spinal reflexes and control of extensor motor tone. The corticospinal tract is the only spinal tract to originate directly from cerebral cortex and is the primary pathway for voluntary, skilled movement. The corticospinal tract fibers originate in layer V of the somatosensory cortical areas (40%), primary motor area (31%), and the premotor area (29%). Fibers from these areas converge with thalamocortical fibers in the corona radiata, continue through the internal capsule, and form the crus cerebri in the midbrain and the cerebral peduncle in the brainstem. These fibers form the pyramids in the medulla and also transmit fibers to the pretectum, superior colliculus, and medial reticular formation. At the convergence of the medulla and spinal cord, the corticospinal tract partially decussates, forming the lateral corticospinal tract (crossed), the anterior corticospinal tract (uncrossed), and the anterolateral corticospinal tract (uncrossed) (Carpenter, 1991; Kandel et al., 1991; Nieuwenhuys et al., 1988).

The lateral corticospinal tract is the largest of these tracts, comprised of 75-90% of the fibers from the pre-decussation corticospinal tract. After crossing over at the level of the medulla, the lateral corticospinal tract is

located in the lateral funiculus, between the posterior spinocerebellar tract and the fasciculus proprius. The anterior corticospinal tract is medial, next to the anterior median fissure, and most of its fibers cross in the anterior white commissure at upper cervical levels. The anterolateral corticospinal tract is found in the lateral funiculus, ventral to the lateral corticospinal tract. Its fibers, still uncrossed, terminate in the base of the posterior horn and the interior gray (Carpenter, 1991; Nieuwenhuys et al., 1988).

The Rubrospinal Tract

The rubrospinal tract originates in the magnocellular region of the red nucleus in the midbrain tegmentum, which receives afferent projections, largely via the cerebral peduncle, from the cerebral cortex, including motor cortex, and the cerebellum. The rubrospinal tract is involved in controlling tone in flexor and extensor muscle groups. The rubrospinal tract decussates in the ventral tegmentum, and then proceeds in the lateral funiculus, with some fibers intermingled with and others anterior to the lateral corticospinal tract (Carpenter, 1991; Nieuwenhuys et al., 1988).

The Reticulospinal Tracts

The reticulospinal tracts include the pontine reticulospinal tract and the medullary reticulospinal tract,

and pertain to facilitating or inhibiting voluntary activity, affecting muscle tone, and influencing respiration, circulation, and sensation. The reticular formation receives multiple afferent projections, especially from motor cortex, premotor cortex, the superior colliculus, and the parietal, occipital, and temporal lobes. The pontine reticulospinal tract, comprised of largely uncrossed fibers, originates in the nuclei reticularis, pontis, caudalis, and oralis in the medial pontine tegmentum, and descends in the medial anterior funiculus. The medullary reticulospinal tract, which contains both crossed and uncrossed fibers, originates in the medial medullary reticular formation, especially in the nucleus reticularis gigantocellularis (lateral to the paramedian region and dorsal to the inferior olivary complex). The medullary reticulospinal tract descends in the lateral funiculus and has a wider distribution than the pontine reticulospinal tract (Carpenter, 1991; Nieuwenhuys et al., 1988).

The Striatum

Nieuwenhuys et al. (1988) note that the striatum has traditionally been considered "extrapyramidal" and therefore largely irrelevant to the corticospinal systems described above. Nieuwenhuys et al. (1988) argue that the striatum, with its system of afferent and efferent systems, plays a key role in voluntary motor activity. The mechanisms for such a striatal influence include the striatal-pallidal-

thalamic connection to premotor cortex, the striatal-nigral connection to the superior colliculus and reticular formation, and the striatal-pallidal-nigral-thalamic connection to the cortex via the nucleus pedunculopontines.

Development of Visual Perception

It is likely that the neuroanatomical structures which adults employ in visual perception and in visuomotor tasks serve similar functions in childhood. However, children's ability to perform tasks requiring visual perception and visuomotor skills increases over time, with corresponding changes in the neuroanatomical structures (Kolb & Fantie, 1889; Spreen et al., 1984; Williams, 1983).

Newborn infants' visual behavior consists primarily of detecting and orienting towards peripheral details or light (Figure 4) (Graham, 1986; Kolb & Fantie, 1989; Lamb & Campos, 1982; Spreen et al., 1984). Visual resolution is quite poor at birth (Lamb & Campos, 1982; Willis & Widerstrom, 1986). At about six weeks, binocular vision is apparent and has become quite functional by around four months of age (Spreen et al., 1984). Also at around four months of age, the infant has begun to attend to nonmoving stimuli at the center of the visual field (Gesell & Amatruda, 1974). Color vision and conjugate eye movements develop in the first six months of life (Gesell, 1977; Graham, 1986; Kolb & Fantie, 1989; Spreen et al., 1984). As the first year proceeds, the infant becomes more and more

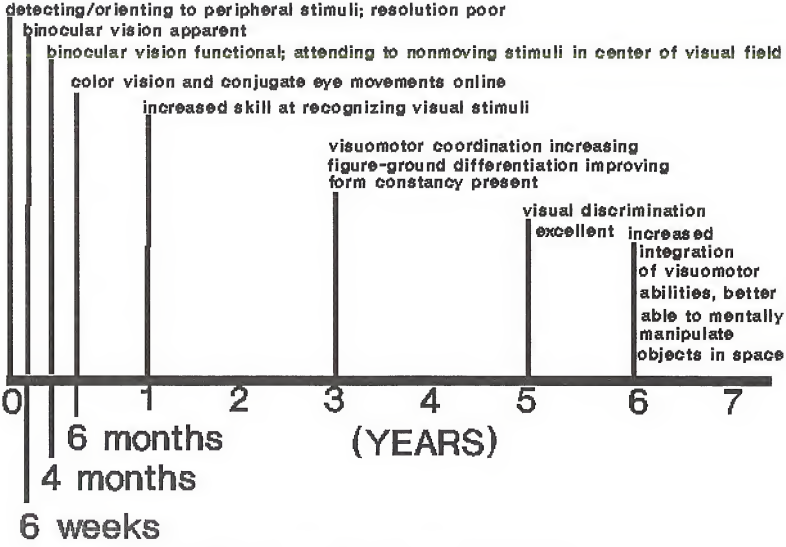

Figure 4. Timeline of Visual Development

skillful at recognizing visual stimuli (Lamb & Campos, 1982; Spreen et al., 1984).

Less dramatic changes in visual ability continue into later childhood (Graham, 1986; Williams, 1983). Visuomotor coordination (e.g., hand-eye coordination) grows rapidly from three to five years of age (Williams, 1983). Figure-ground differentiation is present at three to four years of age and improves rapidly from four to six years of age (Williams, 1983). Form constancy, or the idea that objects' size and shape are permanent, regardless of the size or shape of its retinal image, is present by three years of age and increases greatly at six to seven years of age (Williams, 1983). By five years of age, children have become quite skilled at visual discrimination tasks and rely almost solely on visual discrimination abilities to perform all visuomotor tasks (Williams, 1983). At six years of age, children are becoming more adept at both integrating visuomotor abilities and at mentally manipulating objects in space (Williams, 1983). All of these visual abilities appear to have reached adult levels by nine or ten years of age (Williams, 1983). Thus, many changes in visual perception occur during middle childhood.

As noted earlier, changes in abilities are typically related to neuroanatomical development. However, before exploring what is currently known about the growth of the neuroanatomical structures of vision, it is important to understand the general processes of neuroanatomical

maturation. In many instances, neuroanatomical development is highly related to the amount and type of interaction with the environment (Carpenter, 1991; Kolb & Fantie, 1989; Lamb & Campos, 1982; Spreen et al., 1984; Williams, 1983; Willis & Widerstrom, 1986). The general processes of neuroanatomical development include specialization of function, cellular proliferation, cellular migration, myelinization, an increase in the number of glial cells, the growth of dendrites and axons, the continuing formation of synaptic connections, and neurochemical development (Kolb & Fantie, 1989; Menkes, Till, & Gabriel, 1990). For visual processes, rapid changes occur in the first year (Kolb & Fantie, 1989; Spreen et al., 1984; Willis & Widerstrom, 1986). In the first six months, the lateral geniculate body, cortical neurons, retinal receptors, and photoreceptors develop, and increased myelinization occurs in the optic radiation (Kolb & Fantie, 1989; Willis & Widerstrom, 1986). Between six and twelve months of age, changes occur in the size of cells in the lateral geniculate nucleus; in the development of the visual cortex; in the number of glial cells, interneurons, and dendritic spines; and in the extent of myelinization in the optic tract, optic radiation, and corpus callosum (Kolb & Fantie, 1989; Spreen et al., 1984).

Visual deprivation in animal studies demonstrates the degree to which visual development depends upon visual stimulation. In monkeys, although visual deprivation in the

early postnatal period has no impact upon the orientation columns, any interference with binocular vision results in decreased binocular cells in primary visual cortex (Carpenter, 1991). In addition, monocular deprivation during the first two months of life in kittens changes the lateral geniculate body and the sizes of the ocular dominance columns: lateral geniculate body cells for the deprived eye are smaller than the nondeprived eye, and the ocular dominance columns for the normal eye become larger than the ocular dominance columns for the deprived eye (Hubel & Wiesel, 1970). Such changes cannot be reversed by later visual experience (Hubel & Wiesel, 1970; Wiesel & Hubel, 1965).

Development of Motor Skills

Although visuomotor skills were discussed briefly, it is important to also attend to the development of general motor skills. At birth, reflexive and random motor movements are present (Figure 5) (Kolb & Fantie, 1989; Spreen et al., 1984; Willis & Widerstrom, 1986). These reflexive movements include orienting towards tactile stimulation of the face, blinking to light, sucking, and extending limbs towards or withdrawing body parts from certain stimulation (Kolb & Fantie, 1989; Willis & Widerstrom, 1986). The infant slowly develops intentional motor skills, starting with lifting the chin (one to two months old) and reaching and grasping (by twelve weeks old)

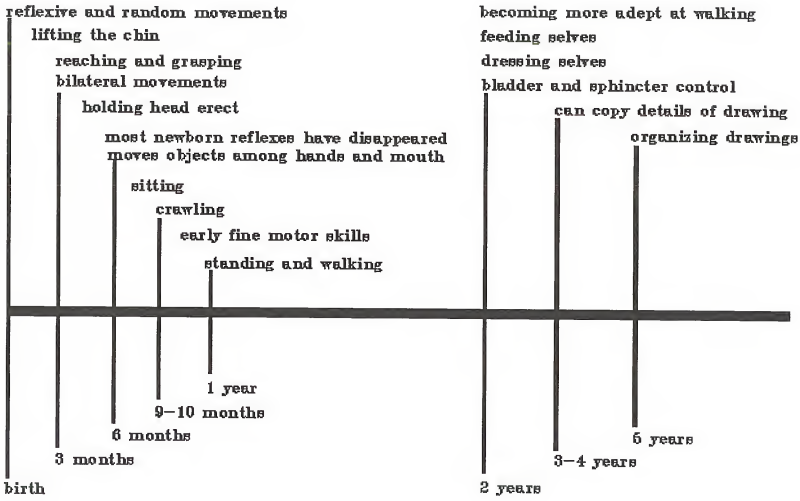

Figure 5. Timeline of Motor Development

(Gesell & Amatruda, 1974; Kolb & Fantie, 1989; Spreen et al., 1984; Willis & Widerstrom, 1986). At three months, the infant's movements tend to be bilateral, and at four months of age, the infant becomes able to hold his/her head erect and turn towards peripheral objects or sounds (Gesell, 1977; Kolb & Fantie, 1989; Willis & Widerstrom, 1986). By six months of age, many newborn reflexive movements have disappeared (Willis & Widerstrom, 1986). Willis and Widerstrom (1986) note that such reflexes, although they encourage the infant's development of muscle tone, of kinesthetic awareness, and of primitive skills for interacting with the environment, would inhibit the acquisition of complex motor programs such as walking.

In the second half of the first year, the infant is able to grasp objects with two hands and manipulate objects from one hand to the other and to the mouth (around six months), learns to sit (seven to eight months old), crawl (nine to ten months old), perform some fine motor skills (around ten months old), and stand and walk (around one year old) (Gesell, 1977; Gesell & Amatruda, 1974; Kolb & Fantie, 1989; Spreen et al., 1984). Reflexes are developed during this period which tend to protect the child from injury and to facilitate coordinated motor actions (Willis & Widerstrom, 1986). During the second through fourth year, children become more adept walkers, learn to feed and dress themselves, and develop bladder and sphincter control (Gesell, 1977; Gesell & Amatruda, 1974; Kolb & Fantie, 1989;

Spreen et al., 1984). In addition, during early childhood increased coordination of various limb movements develops (Gesell, 1977; Gesell & Amatruda, 1974; Kolb & Fantie, 1989; Williams, 1983).

In terms of fine motor skills such as drawing, the child is able to attend to features of a stimulus when copying it at three and four years of age, but drawings show minimal organization until about five years of age (Gesell, 1977; Williams, 1983). From five to seven years of age, the ability to copy drawings rapidly increases and continues to develop slowly until around ten years of age (Williams, 1983). From five to ten years of age, both gross and fine motor programs become increasingly coordinated (Gesell, 1977).

The improved motor skills in infancy and early childhood are probably related to neuroanatomical changes in the first years of life, such as increased myelinization in the spinal cord and maturation of cortical motor areas and corticospinal connections (Spreen et al., 1984). In particular, myelinization changes are observed in the pyramidal tract in the first 12 months and in associational areas and the corpus callosum in the first 24 months (Kolb & Fantie, 1989).

Thus far, visual and motor functions in normal adults and children have been explored. In addition to the knowledge gained from examining normal functioning, a

variety of neurological disorders provide information about mature visual perception and about visuomotor skills.

Visuoperceptual Disorders in Adulthood

A variety of disorders of visual perception have been described (Bauer, 1993; Benton & Tranel, 1993; Ellis & Young, 1991; McCarthy & Warrington, 1990). Benton and Tranel (1993) classify these disorders into visuoperceptual, visuospatial, and visuoconstructive skills. Visuoperceptual skills include visual analysis (such as discrimination, recognition, and figure-ground differentiation), visual synthesis, and color recognition. Visuospatial skills involve localization of objects in space, judgment of direction and distance, and topographical orientation. Visuoconstructive skills entail reproducing information via assembly and drawing (Benton & Tranel, 1993).

Warrington and McCarthy's (1990) conceptualization of visuoperceptual problems includes three primary processes: visual sensory processing (e.g., ability to recognize whether shapes are the same or different), perceptual processing (e.g., ability to process unusual perspectives of an object in order to recognize it), and visual semantic processing (e.g., ability to recognize an object's function).

Because it lacks the ambiguity associated with trying to make a distinction between "perception" and "semantic processing," Ellis and Young's (1991) model of object

identification is more compelling (Bauer, 1993). Ellis and Young (1991) conceptualize object recognition as consisting of (1) perceiving the initial representation of the object (i.e., information about edges, brightness contrasts, color, etc.), (2a) forming a viewer-centered view of object (i.e., perceiving a distinct object as it appears in the visual field) and (2b) forming an object-centered view of the object (i.e., mentally manipulating the viewer-centered object in space so that it can be more readily recognized), (3) translating these representations of the object into object recognition units, (4) accessing the semantic system to ascribe meaning to the item, and (5) naming or otherwise indicating recognition of the object. Although this schema is an oversimplification in practice (e.g., patients identified as having deficits accessing the semantic system often have subtle basic perceptual difficulties as well), it provides a useful framework for considering visuoperceptual deficits.

Observed diseases whose primary defect is in visual perception and object recognition despite adequate visual acuity include but are not restricted to achromatopsia, simultagnosia, apperceptive agnosia, associative agnosia, deficits in shape discrimination, color anomia, and optic aphasia (Bauer, 1993; Benton & Tranel, 1993; Ellis & Young, 1991; Warrington & McCarthy, 1990). These disorders will be discussed according to Ellis and Young's (1991) schema, despite the oversimplification necessary for such classifi-

cation. Lesions of primary visual cortex result in "blind spots" in vision and in impaired shape discrimination, thereby interfering with the initial representation of the object (Benton & Tranel, 1993; Ellis & Young, 1991; Warrington & McCarthy, 1990). Achromatopsia, or inability to see color in all or part of the visual field, also hinders the initial representation of the object (Bauer, 1993; Benton & Tranel, 1993; Ellis & Young, 1991; Warrington & McCarthy, 1990). Achromatopsia typically results from lesions in the lingual and fusiform gyri or the white matter at the posterior lateral ventricle (Bauer, 1993; Benton & Tranel, 1993; Warrington & McCarthy, 1990).

Simultagnosia, or inability to perceive and integrate multiple stimuli, probably reflects difficulties in forming viewer- and object-centered views of multiple objects (although simultagnosia is among the most difficult disorders to classify into Ellis and Young's (1991) schema) (Bauer, 1993; Benton & Tranel, 1993; Warrington & McCarthy, 1990). Simultagnosia is typically associated with bilateral parieto-occipital lesions or occipitotemporal lesions (Bauer, 1993; Benton & Tranel, 1993; Warrington & McCarthy, 1990). Apperceptive agnosia, or inability to recognize, copy, or match an object, is probably also a deficit in forming viewer- and object-centered views of objects (Bauer, 1993; Benton & Tranel, 1993; Ellis & Young, 1991; Warrington & McCarthy, 1990). Apperceptive agnosia typically results from parieto- or temporo-occipital lesions (Bauer, 1993;

Benton & Tranel, 1993; Warrington & McCarthy, 1990). Deficits in translating from the viewer-centered to the object-centered view of an object are associated with right inferior parietal lesions (Ellis & Young, 1991; Warrington & McCarthy, 1990).

Difficulties accessing the semantic system are probably involved in associative agnosia, when the patient can copy or match objects but cannot identify their function (Bauer, 1993; Ellis & Young, 1991; Warrington & Young, 1990). Associative agnosia typically results from bilateral occipitotemporal lesions, mesial occipital lesions, or right occipital lesions (Bauer, 1993; Ellis & Young, 1991; Warrington & McCarthy, 1990).

Color anomia (inability to name colors despite ability to match) and optic aphasia (inability to name objects presented visually despite understanding the object's function and being able to name items based on auditory or tactile information) represent deficits in naming (Bauer, 1993; Ellis & Young, 1991; Warrington & McCarthy, 1990). Color anomia and optic aphasia are associated with left posterior lesions (Bauer, 1993; Ellis & Young, 1990).

Warrington and McCarthy (1990) conceptualize visuospatial disorders as including deficits in integrating complex information for estimation of location (such information includes the retinal image from each eye, and information about head and eye position and movement). In addition, visuomotor coordination involves coordination of

spatial information with somesthetic information about body position. Attention to different spatial areas and ability to mentally represent multiple items in space also play a role in visuospatial phenomena.

Defects in visuospatial abilities include inability to localize an item in space, discriminate an item's spatial properties (e.g., bisect a line), distinguish position (e.g., to recognize when two items are arrayed similarly on their respective pages), recognize orientation (e.g., to recognize whether two lines are parallel), search fully a region of space, and detect or count items within an array or series (Benton & Tranel, 1993; Warrington & McCarthy, 1990). In addition, visual neglect is an often dramatic instance of ignoring a major portion of the spatial environment (Benton & Tranel, 1993; Heilman, Watson, & Valenstein, 1993; Warrington & McCarthy, 1990).

Visuospatial difficulties are typically related to occipitoparietal lesions, frequently bilateral, although temporal regions are also sometimes involved (Benton & Tranel, 1993; Warrington & McCarthy, 1990). In particular, optic ataxia, or impaired reaching for an object in space, localizes to the posterior parietal or occipitoparietal area (Benton & Tranel, 1993; Warrington & McCarthy, 1990). Deficits in depth perception are associated with lesions in superior visual association cortex (Benton & Tranel, 1993). Visual neglect, which typically results from lesions in temporoparietal regions, has also been associated with

lesions in the dorsolateral frontal lobe, cingulate gyrus, striatum, thalamus, mesencephalic reticular formation, and the posterior limb of the internal capsule (Heilman, Watson, & Valenstein, 1993).

The final type of adulthood visuoperceptual problem identified by Benton and Tranel (1993), visuoconstructive disorders, relates to difficulties in both visual perception, as described above, and praxis, as described below.

Motor Impairments in Adults and Children

Apraxia in adults and developmental dyspraxia in children are disorders of skilled movements which have implications for normal motor functioning (Cermak, 1985; Heilman & Rothi, 1993). Developmental dyspraxia represents a failure to develop coordinated motor programs; apraxia refers to the loss of previously acquired motor programs (Cermak, 1985; Heilman & Rothi, 1993). Developmental dyspraxia tends to reflect a difficulty in sensory integration and motor planning, whereas apraxia typically is a deficit in executing sequenced skilled movements (Cermak, 1985; Rothi & Heilman, 1993).

Examination of developmental dyspraxia has indicated that normal motor skill acquisition consists of three phases: first, a cognitive understanding of the necessary motor actions develops; second, movement becomes more coordinated as practicing provides feedback; and third, a

motor program develops, allowing performance of the motor sequence with minimal conscious attention (Goodgold-Edwards & Cermak, 1989).

Dyspraxic errors correspond to these three steps, and consist of errors in planning, in execution, and in specific movements (Goodgold-Edwards & Cermak, 1989). Planning errors can be related to cognitive deficits, spatial disorientation, visuoperceptual or visuospatial problems, tactile-perceptual problems, or a poorly developed body schema (Cermak, 1985; Goodgold-Edwards & Cermak, 1989; Murray, Cermak, & O'Brien, 1990). Execution errors occur when visual, proprioceptive, or kinesthetic feedback is deficient, or when pre-movement preparation is inadequate (Goodgold-Edwards & Cermak, 1989). Specific movement errors result from an inability to accurately produce intended movements, or to perform particular components of a sequence (Goodgold-Edwards & Cermak, 1989).

Cermak (1985) hypothesized several possible areas of brain dysfunction which may result in developmental dyspraxia. Thalamic lesions, particularly in the area of the thalamus related to somatosensory and auditory functioning, may contribute to deficits in somatosensory functions (Cermak, 1985). Cerebellar dysfunction also results in deficits in coordinating motor sequences (Cermak, 1985). Implicit in Cermak's (1985; Goodgold-Edwards & Cermak, 1989) conceptualization of dyspraxia is the potential for dyspraxia to result from deficits in spatial

processing (e.g., posterior parietal regions), somatosensory processing (e.g., postcentral areas), motor planning and initiation (e.g., the supplementary motor and premotor areas), and motor execution (the premotor and motor areas).

In the area of adult voluntary movement, Warrington and McCarthy (1990) explored simple voluntary movements, concluding that bimanual coordination localized to the supplementary motor area, imitating hand position localized to left parietal regions, and imitation of unfamiliar motor sequences localized to left parietal and left frontal regions.

Heilman and Rothi (1993) conceptualize the various forms of apraxia in adults as resulting from different lesions in the systems necessary for praxis. Sensory areas frequently necessary for praxis include visual cortex (for imitation) and Wernicke's area (for comprehension of instructions). The second necessary step to praxis is access to praxicons (programs of skilled movement), which are postulated to exist in the angular gyrus or supramarginal gyrus, usually of the left hemisphere. Next, the premotor and supplementary motor areas initiate and control the movement both directly and via the motor cortex. The final major aspect of this schema is the corpus callosum. Lesions in the corpus callosum can result in disconnections between right and left hemisphere areas necessary for movement (e.g., a right handed patient might not be able to carry out commands with his left hand because

of a disconnection of the right motor areas from the left praxicons). In addition, Heilman and Rothi (1993) note that disruptions of the striatal-pallidal-thalamic-cortical circuits can disrupt various steps of praxis.

For apraxia in adults, Heilman and Rothi (1993) have noted that difficulties with coordinated movement can relate to damage to premotor or motor cortex, to parietal regions (spatial disorientation, poorly developed body schema, possible location of motor engrams), to callosal regions (disconnection of motor engrams from motor cortex), or to the striatal-pallidal-thalamic-cortical circuits (which provide input to cortical areas).

Cerebral Lateralization and Visuomotor Skills

As evident from the previous discussion, right hemisphere lesions in adults often result in greater impairment in visuoperceptual and visuospatial skills than left hemisphere lesions (Bauer, 1993; Benton & Tranel, 1993; Heilman & Rothi, 1993; Tranel, 1992). Lateralization of function has been recognized as an important aspect of cortical organization for many years (Kinsbourne, 1989; Kolb & Whishaw, 1990). In brief, for right-handers the left hemisphere is generally dominant for language functions (e.g., comprehending speech, speaking, reading, writing, and verbal memory), for complex voluntary movement (e.g., writing or the praxicons mentioned above), and for arithmetic (Heilman & Rothi, 1993; Kinsbourne, 1989; Kolb &

Whishaw, 1990; Tranel, 1992). The right hemisphere tends to be dominant in interpreting visual information other than written information, in visuospatial functions, in face recognition, in comprehending sounds other than speech, in emotional processing, and in nonverbal memory (Bauer, 1993; Benton & Tranel, 1993; Heilman, Bowers, & Valenstein, 1993; Kinsbourne, 1989; Kolb & Whishaw, 1990; Ornstein, Johnstone, Herron, & Swencionis, 1980; Tranel, 1992; Young, 1983). Positron emission tomography indicates that the right hemisphere is more active in object identification and visuospatial tasks, with presumed callosal connections to and from the left hemisphere (McIntosh et al., 1994).

Although the two hemispheres work in tandem, right hemisphere functions tend to relate more directly to visuoperceptual and visuospatial skills and, to the degree that visuoperceptual skills are a prerequisite for visuomotor performance, to perceptual-motor skills. Despite the right hemisphere's dominance in this area, the left hemisphere also plays an important role in visuomotor tasks because (1) language functions are likely to relate to visuoperceptual and visuomotor skills indirectly, (2) the motor dominance of the left hemisphere (for right-handers) means that the left hemisphere motor areas are crucial to movement, and (3) the praxicons for complex, sequenced movement are believed to be stored in the left hemisphere (Heilman & Rothi, 1993; Miller & Rohr, 1980; Ornstein et al., 1980).

Although the typical cerebral lateralization in adults has been widely studied, it is less clear precisely how and when such lateralization occurs. Much evidence suggests that cerebral lateralization is innate and present from birth (Kinsbourne, 1989; Young, 1983). For example, Wernicke's area (crucial to language processing) in the newborn infant is larger on the left than on the right side (Kinsbourne & Hiscock, 1981). In addition, left-sided brain injury prior to 1 year of age results in lower verbal and performance abilities, whereas similar injury to the right hemisphere results only in lower performance abilities, suggesting that the left hemisphere is specialized prior to one year of age (Kinsbourne, 1989; Woods, 1980). Furthermore, as in adults, infants demonstrate greater left-hemisphere excitation to speech and greater right-hemisphere excitation to non-language sounds (Kinsbourne, 1989; Kinsbourne & Hiscock, 1981). Evidence also suggests that a motor preference to use the right hand is present for most infants in the first months after birth (Bryden & Saxby, 1986; Kinsbourne, 1989; Kinsbourne & Hiscock, 1981).

However, other evidence suggests that cerebral lateralization is not "set in stone" until later in childhood. For example, the right-handed preference is not as common in infants as it is in adults, suggesting that further development occurs to solidify left hemisphere dominance (Bryden & Saxby, 1986; Kinsbourne, 1989). Indeed, a number of studies have not demonstrated a consistent

right-handed preference until around age 8 (Bryden & Saxby, 1986; Kinsbourne, 1989). Similarly, handedness and other measures of lateralization, such as eye preference, foot preference, and auditory preference become more highly correlated with one another in late childhood, suggesting that these preferences had not crystallized at earlier ages (Bryden & Saxby, 1986; Kinsbourne, 1989; Kinsbourne & Hiscock, 1981). Thus, it appears that a certain amount of cerebral lateralization is present at birth, but that lateralization continues to develop throughout at least the first ten years of life.

Learning Disabilities: An Overview

Learning disabilities comprise a final set of neuropsychological disorders with particular relevance to visual and visuomotor skills (and with particular relevance to this project, since learning disabled children comprise one of the three samples). A diagnosis of learning disability means that, in the absence of discernible cognitive, sensory, neurological, emotional, or environmental causes, a child experiences significant difficulty learning a particular skill (Rourke, 1989; Spreen et al., 1984; Taylor, 1988a).

Despite the fact that children and adults with learning disabilities do not display consistent patterns of neuroanatomical abnormalities that are clearly attributable to a learning disability, the type of difficulties they

experience suggests that a currently undetectable neurological abnormality does exist (Rourke, 1975; Spreen et al., 1984; Taylor, 1988a, 1988b). Indeed, a small but growing body of literature is detecting morphological abnormalities in the brains of some developmental dyslexics (Dool, Stelmack, & Rourke, 1993; Hynd & Semrud-Clikeman, 1989a, 1989b; Hynd, Demrud-Clikeman, Lorys, Novey, & Eliopulos, 1990; Leonard et al., 1993). Specific abnormalities that have been discerned in some but not all cases include atypical patterns of hemispheric symmetry, abnormalities in brain electrical activity, focal lesions in left frontal and perisylvian regions, unusually small insular regions, extra gyri in the parietal operculum, and multiple Heschl's gyri (Dool, Stelmack, & Rourke, 1993; Hynd & Semrud-Clikeman, 1989a, 1989b; Hynd et al., 1990; Leonard et al., 1993). However, as of yet, no clear pattern has emerged via which learning disabilities can clearly be associated directly to brain abnormalities (e.g., control subjects without learning disabilities often have morphological abnormalities as well) (Hynd et al., 1990; Leonard et al., 1993).

Although Morris (1989), Rourke (1989), and Taylor (1988a) have made excellent cases for improving the categorization of learning disabilities, no classification system has emerged that maximizes descriptiveness, reliability, and validity. The traditional subtypes of learning disabilities include dyslexia (difficulties

reading), dysgraphia (difficulties writing), and dyscalculia (difficulties with arithmetic) (Spreen et al., 1984). Although in theory these subtypes seem straightforward, in practice the variability of difficulties experienced by learning disabled children defies such a discrete classification system (Morris, 1989; Taylor, 1988a).

In addition to the heterogeneity caused by the many different deficits potentially causing learning disabilities, Taylor (1988a) has identified numerous areas in which learning disabled children will differ, producing even greater heterogeneity. Such areas include environmental factors (the family and the school's reaction to, treatment of, and expectations of the child), biological factors, cognitive abilities, temperament, self-concept, attitude towards school and learning, comorbid disorders (attention-deficit disorder has a particularly high comorbidity rate with learning disabilities), and local standards for defining learning disability.

Gender differences also account for some of the heterogeneity (Vogel, 1990). Many more males, in estimated ratios ranging from 2:1 to 5:1, are diagnosed as learning disabled; however, females tend to evidence greater deficits when diagnosed (Taylor, 1988a; Vogel, 1990). In particular, female learning disabled children typically display lower Full-Scale, Verbal, and Performance IQs, and have greater deficits in academic achievement. The only areas in which female learning disabled children typically display higher

scores than males are in the Coding subtest of the WISC-R and in written expressive language skills (Vogel, 1990).

Vogel (1990) hypothesized several possible reasons for these differences, including sample bias (e.g., male children are more likely to be identified as LD because they are likely to display more disruptive behavior than females). Indeed, Shaywitz, Shaywitz, Fletcher, and Escobar (1990) examined differences between children identified as learning disabled by the school system and children identified through their research protocol, concluding that the proportion of learning disabled males to learning disabled females is approximately 1.2 males per 1 female. They found that increased behavior problems in males resulted in greater teacher identification of learning disabilities in males. Furthermore, they note that the traditional view that many more males than females are learning disabled results in underdiagnosis of learning disabled females by physicians.

Dyslexia

It is likely that dyslexia, considered to be the most common learning disability, is extremely variable in terms of the specific deficit which causes the reading difficulty (Taylor, 1988a; Spreen et al., 1984; Vellutino, Scanlon, & Tanzman, 1994). Reading consists of a wide range of specific functions, and deficits affecting any of these functions would result in reading problems (Friedman, Ween,

& Albert, 1993; Taylor, 1988a). Traditionally, the first step in reading is visual analysis, resulting in identification of the visual pattern of the letters or the word. Once visual analysis occurs, reading proceeds in two different ways (Friedman et al., 1993; Taylor, 1988a). The word can be matched to the visual image of the word in memory (lexical or orthographic reading), or can be "sounded out" and then identified in the same way that speech is interpreted (phonological reading) (Friedman et al., 1993; Taylor, 1988a; Vellutino et al., 1994).

Although this schema for reading is conceptually appealing, reading is much more complex (Vellutino et al. 1994). General language skills, especially auditory comprehension, have significant impact on reading ability, and semantics as well as syntactic knowledge greatly facilitate reading (Vellutino et al., 1994).

Bradley (1983) suggests that lexical reading occurs first developmentally, and that phonological reading develops later in childhood (beginning around age 7). In support of this hypothesis, Bradley (1983) demonstrates that children experience a period when they can use phonological cues for spelling, but not for reading. In addition to lexical and phonological reading, Morris (1991) indicated that a third and final developmental stage occurs when the child becomes able to analyze sets of letters which form a meaningful subset of a word (e.g., prefixes, roots, suffixes).

Difficulties can occur in any one of these steps (Friedman et al., 1993; Taylor, 1988a). For example, problems in visual discrimination can affect the ability to recognize letters and to distinguish between letters (Spreen et al., 1984). Difficulties in sequencing or in spatial perception can also result in visual discrimination errors, such as mistaking "two" for "tow" (Spreen et al., 1984; Taylor, 1988a). Indeed, Bradley's (1983) research indicated that spatial difficulties are present in children who are 18 months behind in reading. However, Vellutino et al. (1994) conclude that the incidence of generalized language difficulties is far greater in dyslexia than the incidence of visual or visuospatial defects.

As further examples, problems with orthographic memory may make it difficult to recognize letters and words. Bradley (1983) demonstrated that children who had difficulties on a task involving visual memory for letter sequences, when compared to children who attained perfect scores on this task, demonstrated more errors on reading phonetically irregular words. Lexical reading can also be impeded if the lexicon is damaged, or is disconnected from the anatomical structures employed to analyze the written word (Friedman et al., 1993).

Deficits in auditory processing or phonological processing may cause difficulties in translating information from written to oral form, and vice versa (Spreen et al., 1984; Taylor, 1988a; Vellutino et al., 1994). In support of

this possibility, Bradley (1983) found that children who were 18 months behind their expected reading level could perform purely visual and purely auditory tasks, but experienced difficulty translating from visual to auditory information and vice versa. Similarly, problems in auditory organization can make phonological processing of language more difficult (Vellutino et al., 1994). In fact, Bradley (1983) found that children who were 18 months behind their expected reading level experienced difficulty on an auditory organization task.

Examination of adults who have lost reading ability following injury also contributes important information to the attempt to understand dyslexia (Friedman et al., 1993). In adults, damage to the occipital lobes, the corpus callosum, or the angular gyrus results in pure alexia, defined as severely impaired comprehension of written language which is frequently accompanied by difficulty copying and by written acalculia (Friedman et al., 1993). Alexias have also been reported to result from lesions in precentral cortex, postcentral cortex, the supramarginal gyrus, and the inferior, medial, and superior temporal gyri (Friedman et al., 1993).

Dysgraphia

Dysgraphia may relate either to general difficulties with fine motor skills (such difficulties were discussed with apraxia and developmental dyspraxia, so will not be

reexamined here), or to specific difficulties with writing language (Roeltgen, 1993; Spreen et al., 1984). Writing, like reading, has two primary routes, lexical and phonological (Roeltgen, 1993). Based on adults with lexical agraphia (inability to write irregular words), the region most important to lexical writing is the junction of the posterior angular gyrus and the parieto-occipital lobule, extending into the white matter (Roeltgen, 1993). Lexical agraphia has also resulted from lesions in the right parietal lobe, the left posterior temporal lobe, the left frontal lobe, and the left caudate nucleus (Roeltgen, 1993). Phonological agraphia, or inability to write unfamiliar words or nonwords, results primarily from damage to the supramarginal gyrus or the insula medial to the supramarginal gyrus (Roeltgen, 1993). Less commonly, phonological agraphia has been linked to damage to the caudate nucleus, internal capsule, and thalamus (Roeltgen, 1993).

Dyscalculia

Dyscalculia can take a number of forms, including difficulties with verbalizing arithmetic functions, with reading and/or writing arithmetic functions, with comprehending the nature of the arithmetic functions, with placing the components of a written arithmetic task in appropriate spatial relations to one another, with sequencing the components of an arithmetic function,

shifting between arithmetic response sets, judgement and planning, or with using the many memory functions necessary for arithmetic (Levin, Goldstein, & Spiers, 1993; Spreen et al., 1984; Rourke, 1993). Rourke (1993) has reported arithmetic disabilities to be associated features of both nonverbal learning disabilities (discussed below) and language disabilities. Reading, writing, spatial functions, and sequencing functions were discussed above, and therefore will not be reviewed again.

Nonverbal Learning Disabilities

Rourke (1989, 1994) has been the primary proponent of a nonverbal learning disability syndrome. He has identified associated deficits in the following areas: tactile and visual perception, complex psychomotor skills, attention, exploratory behavior, tactile and visual memory, concept formation, problem-solving, oral-motor praxis, prosody, phonology-semantics, and verbal comprehension. These difficulties occur in the context of strengths in auditory perception, simple motor skills, rote memory, auditory and verbal attention and memory, phonology, verbal reception and comprehension, and verbal output. As a result of this pattern of strengths and weaknesses, Rourke (1989, 1994) indicates that these children display academic strengths in graphomotor ability (only after age 8), word decoding, spelling, and verbatim memory, and weaknesses in early graphomotor ability, reading comprehension, arithmetic, and

science. Rourke (1989, 1994) also considers a key aspect of nonverbal learning disability to be social-emotional problems, including poor social skills, emotional difficulties, and abnormal activity level (hyperactivity at age 4-5 and hypoactivity in later childhood).

Little (1993), in her review of the literature, concluded that the empirical evidence for a nonverbal learning disability subtype was robust. However, she noted that insufficient evidence existed to conclude that social-emotional problems are unique to the nonverbal learning disability subtype. Indeed, Voeller (1991) describes social-emotional problems as the core feature of social-emotional learning disability, which in her sample was not consistently associated with the other features reported by Rourke (1989, 1994).

Although Rourke (1989, 1994) hypothesizes that white matter lesions result in the nonverbal learning disability, compelling arguments have been made by other researchers for right hemisphere dysfunction to be the key area of dysfunction in social-emotional difficulties (Voeller, 1991).

Assessment of Visuomotor Skills

Developmental information, visual perceptual problems, difficulties with praxis, and evaluation of learning disabilities provide an overview of the complexity of visual and visuomotor processes. As described earlier, these

visual and visuomotor skills are a crucial component of intellectual development (Piaget, 1927/1977; 1936/1977; 1937/1977; Piaget & Inhelder, 1969; Williams, 1983). Therefore, it is likely that assessing such abilities in childhood would provide a valuable tool in the evaluation of children's neuropsychological functioning. However, few such assessment instruments have received extensive empirical examination of their usefulness in neuropsychological assessment of children. Rather, tests which have been widely used with adults have been extended to children. Further data is necessary to demonstrate empirically that such adult tests can be effectively generalized to children. The Hooper Visual Organization Test (HVOT) (Hooper, 1958) and the Rey-Osterrieth Complex Figure Test (ROCFT) (Osterrieth, 1944; Rey, 1941), which have been used extensively with adults in the assessment of visuospatial and visuomotor skills, have emerged as potentially having some utility in the evaluation of children (Lezak, 1983; Spreen & Strauss, 1991).

The Hooper Visual Organization Test (HVOT)

The HVOT consists of a series of 30 items in which the patient is presented with line drawings of objects which have been divided into two or more parts and randomly arranged on the page (Hooper, 1958). The patient must mentally rotate and integrate the pieces of the object in order to identify the object. The HVOT results in two

different kinds of information: (1) the score, or the total number correct, and (2) the number of isolate responses (Hooper Visual Organization Test manual, 1983; Lezak, 1983; Spreen & Strauss, 1991). In addition, three other sources of information from the HVOT are perseverations, bizarre responses, and neologisms (Hooper Visual Organization Test manual, 1983; Lezak, 1983; Spreen & Strauss, 1991. Isolate responses are errors which occur when one of the pieces of the object resembles a different object (e.g., the back portion of a mouse, including the tail, looks like a pipe) (Hooper, 1958; Hooper Visual Organization Test manual, 1983; Lezak, 1983). When the patient names this piece of the object rather than integrating the various pieces of the object, this is considered an isolate response (Hooper, 1958; Hooper Visual Organization Test manual, 1983; Lezak, 1983). Although intended to measure visuospatial and object recognition ability, the HVOT also requires naming; thus, naming is a confounding factor in interpretation of the HVOT (Spreen and Strauss, 1991).

HVOT isolate response errors

Walker (1956), in a study of 38 neuropsychiatric patients (no diagnoses were specified), found that the number of isolate response errors was significantly different for neuropsychiatric patients with definite or suspected cortical involvement than for neuropsychiatric patients with no cortical involvement. However, he noted that the low cutoff (1 or fewer isolate response errors to

be considered within the normal range) greatly increased the likelihood of false positive errors (Walker, 1956).

In a sample of 33 schizophrenics, Walker (1957) found that those schizophrenics who had 1 or no isolate response errors on the HVOT were more likely to be discharged within one year after administration of the HVOT than those schizophrenics with 2 or more isolate response errors on the HVOT. These data suggest that the number of isolate response errors on the HVOT, at least for schizophrenic patients, is related to severity of impairment. These studies by Walker (1956, 1957) are the only empirical evaluation of isolate response errors in adults, and do offer preliminary evidence that identifying such errors may be of importance.

The HVOT's reliability

In terms of the HVOT total score, Hooper (1958) found split-half correlations of .78 and .82 for samples of 166 college students and of 74 psychoneurotic patients (no diagnoses were provided), respectively. Similarly, the split-half correlations calculated by Gerson (1974) ranged from .79 to .80 in his three groups of 16 patients with various forms of organic impairment, 19 functionally impaired (schizophrenic) patients, and 33 normal subjects.

The HVOT's relationship to demographic variables

Hooper (1958) reported that the HVOT generally is unrelated to sex, education, intelligence, and age. However, he did find that intelligence correlated with the

HVOT at .57 for individuals with an IQ between 30 to 80, and that older people received lower scores on the HVOT, presumably the result of normal aging processes (Hooper, 1958). Although Hooper's (1958) claims about the lack of gender effects have sustained subsequent inquiry, his other claims have been called into question by more recent research.

For example, the results of other researchers who examined the relationship between the HVOT and IQ indicate that Hooper (1958) was mistaken when he claimed that IQ was not related to HVOT scores. For example, Wentworth-Rohr, Mackintosh, and Fialkoff (1974), who employed samples of 200 psychiatric patients with unspecified diagnoses, 85 social worker nuns, 51 parochial school principals, and 61 college students, found correlations ranging from .31 to .50 between the HVOT and IQ. Boyd (1981), in samples of 40 organically impaired patients and 40 normal controls, and Tamkin and Jacobsen (1984), in a sample of 211 psychiatric patients with unspecified diagnoses, also demonstrated that the HVOT was related to their estimates of IQ. Therefore, IQ scores should clearly be taken into account when the implications of HVOT scores are considered.

The data regarding the relationship between the HVOT and age and education has been mixed. Wentworth-Rohr et al. (1974) confirmed that, for adults and adolescents, HVOT scores are unrelated to sex, education, and age. Although Boyd's (1981) sample displayed a significant correlation

between the HVOT and age for a neurologically impaired group, he concluded that the severity of illness, rather than age itself, accounted for this difference. However, the research of Tamkin and Jacobsen (1984) and Tamkin and Hyer (1984) indicated that HVOT scores were related to age, as well as to education, in a sample consisting of inpatient psychiatric patients in a Veterans Administration Medical Center. With no information regarding substance abuse history or chronicity of psychiatric illness (both likely to be more severe in the middle-aged to elderly population), Tamkin and Hyer's generalizability to the normal population or to a neurologically impaired population is questionable. The association of age and education with HVOT scores is complicated by Tamkin and Jacobsen's (1984) finding that IQ correlated with both age and education, making it difficult to determine the impact of age and education independent of IQ. Thus, the research on the relationship between age and education on HVOT scores remains inconclusive.

Nevertheless, in order to address the problem of age and intelligence affecting HVOT scores, age- and education-corrected scores based on a regression equation have been developed for the most recent HVOT manual (The Hooper Visual Organization Test Manual, 1983). Education was chosen as an indirect measure of IQ which would be available without testing (The Hooper Visual Organization Test Manual, 1983). For adults over 25, these age- and education-corrected scores would be expected to enhance the HVOT's usefulness;

however, this expectation has not been empirically evaluated.

Criterion validity data for the HVOT

It is almost universally reported, regardless of either definition of neurological impairment or sample size, that mean HVOT scores in adults are significantly lower in neurologically impaired patients than in non-neurologically impaired patients (Boyd, 1981; Gerson, 1974; Hooper, 1952; Tamkin & Kunce, 1985; Sterne, 1973; Wang, 1977). Walker's (1956) sample of 38 neuropsychiatric patients is the only study that did not display significant differences between patients with suspected versus patients with no neurological impairment. Because Walker's (1956) definition of neurological impairment was particularly vague and the preponderance of evidence indicates that the HVOT total score does discriminate between neurologically impaired and non-neurologically impaired patients, it is likely that Walker's (1956) sample size and procedures for classifying patients were inadequate to discern differences between neurologically impaired and non-neurologically impaired patients.

The earliest published research using the HVOT demonstrated that the HVOT distinguished between neurologically impaired versus non-neurologically impaired adults (Hooper, 1952; Hooper, 1958). His data, which were based on a total sample of 200 subjects, indicated that adults with a variety of brain pathology (of inflammatory,

degenerative, toxic, tumorous, or traumatic etiology) received significantly different scores on the HVOT than schizophrenic, psychoneurotic, or normal adults (Hooper, 1952; Hooper, 1958). However, the criteria for these groups appear to be poorly defined, and the specific data for the groups are not available.

Gerson (1974) also found that the HVOT scores were significantly different for his 16 organically impaired adult patients (with brain disease of degenerative, traumatic, or toxic origin) versus either his 19 functionally impaired patients (i.e., schizophrenics) or his 33 normal subjects. The schizophrenic and normal groups were not significantly different. Even when IQ was controlled through an analysis of covariance, the HVOT continued to demonstrate a statistically significant difference among the three groups.

Boyd (1981) examined HVOT data for 40 mildly to moderately neurologically impaired adult patients (10 with closed-head injury; 5 with seizure disorders; 4 with congenital vascular malformations; 3 cases each of normal pressure hydrocephalus, multiple sclerosis, penetrating head injuries, and cerebral vascular accident; 2 cases each of metastatic brain tumor, cortical atrophy, and extrinsic brain tumor; and 1 case each of Huntington's chorea, glioblastoma, and aneurysm) and 40 non-psychotic, non-neurologically impaired patients. The two groups were equivalent in age, education, and Peabody Picture Vocabulary

Test (PPVT) (Dunn, 1965) scores. The HVOT scores for the two groups were significantly different, with mean scores of 23.2 (SD = 3.99) for the neurologically impaired patients and 26.5 (SD = 2.47) for the non-neurologically impaired patients.

Similarly, both Wang (1977) and Tamkin and Kunce (1985) found that HVOT scores were significantly lower for neurologically impaired versus normal adult subjects. Sample sizes were 49 neurologically impaired (15 with left hemisphere damage, 19 with right hemisphere damage, and 15 with bilateral damage; diagnoses are not provided) and 17 non-neurologically impaired subjects (with diagnoses such as low back pain, osteoarthritis, peripheral neuropathy, or spinal cord injury) for Wang's (1977) research, and a total sample size of 66 patients with unspecified diagnoses for Tamkin and Kunce's (1985) study.

Finally, Sterne (1973), in a total sample of 75 adult subjects, demonstrated that the HVOT discriminated between 25 neurologically impaired patients with unspecified diagnoses, 25 patients of indeterminate neurological status, and 25 non-neurologically impaired patients. However, he noted that the HVOT, when given in conjunction with other tests, did not provide additional information for the discrimination of organic versus non-organic patients. Therefore, he indicated that, when sufficient data had been collected, the HVOT was unnecessary for the determination of neurological impairment.

The data from all of these studies indicate that the HVOT is able to discriminate between groups of neurologically impaired versus non-neurologically impaired adult patients, although it is typically endorsed primarily as a screening measure. Despite the HVOT's ability to distinguish between groups of neurologically impaired versus non-neurologically impaired patients, it has been quite difficult to determine a cutoff score that would be useful in classifying individual patients.

The utility of a cutoff score for the HVOT

Hooper (1958) found false positive rates of 3% in a sample of 30 junior high school students, and of 6% in a sample of 166 college students. In Eisenman and Coyle's (1965) study of 23 female student nurses, the lowest score obtained was 26.5, well above the cutoff of 20, and within the 25 to 30 range identified as normal by Hooper (1958).

Further evaluation of the number of false positives and false negatives in a psychiatric population consisting of 20 organic (including diagnoses of disseminated sclerosis, meningitis, lesions, tumors, hemorrhages, Parkinson's disease, and Wernicke's aphasia) and 95 non-organic patients (15 schizophrenic, 13 manic or depressed, 15 neurotic, 10 behaviorally disordered, 9 alcoholic or epileptic, 6 mentally retarded, 13 antisocial, and 14 court-ordered) indicated a false positive rate of 25% and a false negative rate of 30% (Love, 1970). However, when those non-organic patients with an IQ under 75 were excluded, the false

positive rate dropped to 14.5% (Love, 1970). Love (1970) concluded that the HVOT is a useful screening device, but should not be employed alone to discriminate between neurologically impaired and normal people. In particular, his data provided further evidence that IQ scores should be taken into account when examining the significance of HVOT scores.

Other researchers have encountered similar difficulties in determining a cutoff score that would substantially diminish false positive and false negative rates. When evaluating the usefulness of cutoff scores, Gerson (1974) determined that the false negative rate was 0%, but that the false positive rate was 51%. Similarly, the false negative rate was 17% and the false positive rate was 40% for Wang's (1977) subjects. Boyd (1981) found that, using Hooper's cutoff of 20, the false positive rate was 2.5%, but the false negative rate was 85%. All of these data indicate that the HVOT has a particularly high rate of false positives, as well as a fair number of false negatives. Boyd (1981) recommended using a cutoff of 25, which for his sample resulted in a false positive rate of 20% and a false negative rate of 32.5%. The high false positive rate appears to result from the fact that the cutoff is fairly close to the total possible score, and therefore results in a ceiling effect so that scores are normal unless the damage is fairly severe or affects areas crucial to the task. All of the above data do indicate that the HVOT cutoff scores

are quite problematic, and that the HVOT cutoff score is frequently unable to provide a conclusive indication of the presence or absence of neurological impairment.

The HVOT's relationship to location or type of lesion

Despite the fact that the HVOT's most valuable use may be in detecting specific dysfunction rather than identifying whether or not a patient has neurological impairment, the research regarding localization is relatively sparse (Spreen & Strauss, 1991). In terms of the HVOT's ability to distinguish between patients based on the site of neurological impairment, Wang (1977) found that HVOT scores were statistically equivalent, regardless of site of impairment (right, left, or bilateral). Nevertheless, he noted a trend for patients with right hemisphere deficits to obtain lower scores. The HVOT mean scores were 12.21 for patients with right hemisphere deficits, 13.93 for patients with left hemisphere deficits, 10.53 for patients with bilateral deficits, and 22.35 for normal subjects. Boyd (1981) also determined that no statistically significant differences existed within his neurologically impaired group according to laterality of lesion. However, Tamkin and Hyer (1984) provided evidence that right hemisphere dysfunction is associated with decline in HVOT scores in the elderly. Spreen and Strauss (1991) note that Farver and Farver's (1982) results were also consistent with a possible association between right hemisphere dysfunction and low HVOT scores.

Boyd (1981) found that the HVOT did not relate to the acuteness of the illness. However, as would be expected, significant differences occurred on the HVOT according to type of lesion, with "major tissue-destructive lesions (intrinsic brain tumor, cerebral vascular accident)" (p. 18) resulting in lower scores than diseases such as "congenital vascular malformation, multiple sclerosis, [and] normal pressure hydrocephalus" (Boyd, 1981, p. 18).

Concluding remarks on the adult HVOT literature

Thus, the data from adult studies with the HVOT support several conclusions. The HVOT, despite Hooper's (1958) claim to the contrary, is related to IQ. In addition, any use of the HVOT cutoff scores is likely to result in a high number of false negatives and false positives. Finally, research consistently demonstrates that the HVOT scores are significantly lower for neurologically impaired versus non-neurologically impaired adult patients.

Use of the HVOT with children

In the first study involving children (40 7 to 11 year olds, 20 of whom had undefined neurological impairments and 20 of whom were normal), Jackson and Culbertson (1977) found that, using a HVOT cutoff of 21 which eliminated false positives, the false negative rate was 60%. Unfortunately, they present insufficient data to evaluate what cutoff would strike a better balance between false positive and false negative errors. Because later research demonstrated a substantial increase in scores for children in this age

range (Kirk, 1992; Seidel, 1994), Jackson and Culbertson's wide age range probably decreased their ability to determine a cutoff score. Despite these problems in identifying a useful cutoff score, the HVOT scores were significantly different for neurologically impaired versus normal children.

Hilgert and Treloar (1985), employing a sample of 54 elementary school students with a mean IQ of 90.45 who were referred for psychological evaluation by the school, found that the mean HVOT score was 20.70. The HVOT scores correlated significantly (.35) with Performance IQ, but not with Verbal or Full-Scale IQ. Hilgert and Treloar (1985) also concluded that the HVOT scores did not vary according to sex. However, they did determine that age accounted for a large proportion of the variability on the HVOT. Therefore, Hilgert and Treloar (1985) concluded that age and Performance IQ, but not sex, are related to HVOT performance in children.

Kirk (1992) evaluated HVOT scores in 448 male and female children aged 5 to 13 with normal confrontation naming ability. Children were excluded if their scores on either a confrontation naming task or on the HVOT were more than 2.5 standard deviations from the mean for their age. Both age and gender significantly affected performance on the HVOT. Specifically, male children obtained higher scores than female children at all age levels. The male children scored at adult levels (25) by age 12, but the

female children had not achieved adult scores by age 13. In Kirk's sample, older children performed better than younger children, with significant differences for both sexes between the younger ages (5-6) and the older ages (11-13). In addition, younger children displayed more isolate response errors than older children.

Most recently, Seidel (1994) examined the HVOT in 211 randomly selected normal subjects aged 5 through 11 years and 49 children aged 6 through 11 from a clinical sample including children with spina bifida, brain tumors, head injuries, seizure disorders, and severe learning disorders. Inclusion and exclusion criteria for the clinical sample were unclear. His results replicated Kirk's (1992) normal sample's scores, including the pattern of improved performance with increasing age. Like Kirk (1992), he found that the youngest children (5-, 6-, and 7-year-olds) performed significantly worse than the oldest children (10- and 11-year-olds), who approached adult scores. However, unlike Kirk (1992), Seidel (1994) did not find significant differences according to sex.

Seidel's (1994) internal consistency for the HVOT among his normal sample was .723 for a Spearman-Brown corrected odd-even correlation and was .716 for a Cronbach's alpha. These were not different to a statistically significant degree from the internal consistency of .78 and .82 reported by Hooper (1958) (Seidel, 1994). In support of construct validity, Seidel (1994) determined that the HVOT in his

clinical sample correlated significantly (.624) with the Perceptual Organization Deviation Quotient of the WISC-R, but did not correlate significantly with the Verbal Comprehension Deviation Quotient (r=.196) or the Freedom from Distractibility Deviation Quotient (r=.211). In terms of individual subtests of the WISC-R, the HVOT correlated significantly with Block Design (.625), Picture Arrangement (.492), Object Assembly (.488), Picture Completion (.459), and Vocabulary (.312). Along similar lines, Seidel's (1994) principal components analysis for his clinical sample indicated that the HVOT is related to visuospatial and visuomotor skills, and not to verbal information processing abilities or to reading and writing skills. Finally, Seidel (1994) found that, with IQ controlled by matching a subset of his normal sample with the IQs of his clinical sample, his clinical sample nonetheless scored significantly lower than his normal sample on the HVOT.

Concluding remarks on the HVOT literature

In general, the data on the HVOT indicates that it can be a valuable measure for adults when combined with other assessment instruments. Although little research has been done with children, the preliminary normative data and evidence of reliability and validity is promising. Indeed, the HVOT may be more useful with children than with adults. Specifically, the HVOT has a ceiling effect, which results in normal scores for many neurologically impaired adults. Because children in the age ranges studied thus far have not

generally reached the ceiling which adults encounter, the HVOT may be of particular benefit in assessing children. Furthermore, perceptual skills are not as fully developed in children as in adults, and are more highly related to cognitive skills and academic achievement in young children than in adults (Melamed & Melamed, 1985; Williams, 1983). Therefore, tests like the HVOT which examine visual skills may provide information that is more relevant to the neuropsychological functioning of children than of adults. Thus, it is important to continue to empirically investigate the usefulness of the HVOT in children.

The Rey-Osterrieth Complex Figure Test (ROCFT)

The Rey-Osterrieth Complex Figure Test (ROCFT) (Osterrieth, 1944; Rey, 1941) consists of a complex drawing which the patient must copy (Lezak, 1983). The drawing is a rectangular shape, with a large triangle at one end and with a number of details both within and outside the drawing (Lezak, 1983; Rey, 1941). The examiner provides the patient with a new colored pencil each time a section of the drawing is completed, so that the patient's approach style can be evaluated (Lezak, 1983; Spreen & Strauss, 1991). The task requires the patient to correctly perceive the stimulus and to use fine motor skills to reproduce the drawing. Denckla (1994) noted that the ROCFT is an excellent measure of executive function because of its emphasis on motor planning and organizational ability. The ROCFT results in two

primary scores: one for the number of features either correctly copied or approximated, and one for the approach style or organizational quality (Lezak, 1983; Spreen & Strauss, 1991).

The ROCFT total score

Typically, the total score, or the number of features correctly reproduced, is derived by examining eighteen primary details of the figure (Lezak, 1983; Osterrieth, 1944; Spreen & Strauss, 1991). For each of these details, the patient can receive two points if the detail is both correct and properly placed, one point if either its accuracy or its placement (but not both) are correct, and a half point if it is poorly reproduced and incorrectly placed (Lezak, 1983; Osterrieth, 1944; Spreen & Strauss, 1991). Therefore, the maximum score possible is 36.

Despite the fact that Osterrieth's (1944) scoring criteria are poorly operationalized, Carr and Lincoln (1988) obtained an inter-rater reliability of .99 for forty ROCFTs scored by two raters. Similarly, Karapetsas and Kantas (1991) found 92% agreement between two scorers of 80 ROCFTs completed by children. However, neither Carr and Lincoln (1988) nor Karapetsas and Kantas (1991) describe their training method for these raters, and it is likely that they were trained together and developed identical scoring criteria. As some researchers, such as Bennett-Levy (1984), have noted, scorers with various training backgrounds may frequently employ quite different scoring criteria for the

ROCFT. Consequently, more specific criteria for scoring accuracy and placement have been developed (Bennett-Levy, 1984; Mings, 1987). Using such operationalized standards, Bennett-Levy (1984) found inter-rater reliability of .96 for 25 drawings. Unfortunately, Mings (1987) does not report inter-rater reliabilities; however, it is likely, given the specificity of his criteria, that inter-rater reliability would be relatively high.

Organizational scoring for the ROCFT

How patients organize their drawing of the ROCFT is also an important indicator of brain function. For example, Osterrieth (1944) reported that 83 percent of his normal adult sample organized their drawing using some organizational structure (reported in Lezak, 1983). Both Visser (1973) and Binder (1982) found that lack of organization is frequently indicative of brain damage (reported in Lezak, 1983). Similarly, research has indicated that subjects' approach to the drawing is significantly correlated with the total score for the drawing (Bennett-Levy, 1984; Waber & Holmes, 1986).

To score approach style, Osterreith (1944) identified seven approaches to copying the figure: (1) beginning with the rectangle and adding the details, (2) beginning with a detail, completing the rectangle, then finishing the details, (3) beginning with the outline of the figure, then filling in details, (4) placing details without any organizing structure, (5) drawing details with no

organization whatsoever, (6) drawing a different object, and (7) scribbling a figure which is unrecognizable (reported in Lezak, 1983).

Because Osterrieth's (1944) approach styles are qualitative, a number of researchers and clinicians have developed scoring criteria which operationalize specific standards for determining approach style. For example, Bennett-Levy (1984) developed a strategy score, based on two subscores: one subscore based on the amount of continuation (i.e., when a line is drawn continuously, rather than in separate pieces), and one subscore for the amount of symmetry (i.e., when symmetrical aspects of the drawing are drawn sequentially). For a similar purpose, Waber and Holmes (1985) have devised a system based on specific details of the drawing to distinguish five levels of increasing organization. These levels of organization correlate highly ($r = .82$) with clinical impressions of the drawing, and have high inter-rater reliability (.88 to .94) (Waber & Holmes, 1985, 1986).

The ROCFT's relationship to demographic variables

The effects of a number of demographic variables on adults' performance on the ROCFT have been examined. In terms of age, King (1981), in a sample of 114 subjects with neurological impairment (no diagnoses specified) and 71 normal control subjects, found that subjects over 60 years of age, regardless of whether they had neurological disease, displayed poorer performances on the ROCFT total score than

subjects under 60. Similarly, Bennett-Levy (1984) demonstrated in a sample of 107 normal subjects that age was significantly correlated with the ROCFT total score. Ardila, Rosselli, and Rosas (1989), in a sample of 200 normal right-handed subjects, concluded that age affected ROCFT scores only for poorly educated subjects, suggesting that an interaction effect may exist for age and educational level.

Intelligence and educational level have also been associated with the ROCFT (Spreen & Strauss, 1991). King (1981) and Bennett-Levy (1984) both found that IQ was significantly correlated with adults' ROCFT performance, and Spreen and Strauss (1991) report correlations between the ROCFT and IQ ranging from .23 to .47. Furthermore, Ardila et al.'s (1989) results indicated that educational level significantly affected the ROCFT.

King (1981) found that adult subjects' sex did not significantly affect scores on the ROCFT. However, Bennett-Levy (1984) and Ardila et al. (1989) found that, for poorly educated subjects, male subjects' copies of the ROCFT were significantly better organized than females' drawings. Similarly, Casey, Winner, Hurwitz, and DaSilva (1991) found that, for a sample of 244 college students, subjects' sex did not significantly affect ROCFT scores. These results indicate that, as for age, there may be an interaction effect for subjects' sex and educational level.

Validity data for the ROCFT

In terms of the validity of the ROCFT, King (1981) found that the copy score for adults' ROCFT correlated significantly with the Wechsler Memory Scale (Wechsler, 1945) visual recall, suggesting that both assess similar visuoconstructive skills. In support of criterion validity, the ROCFT total score was significantly better for a control group than for patients with brain injuries (King, 1981).

The ROCFT's relationship to location of lesion

Visser (1973) and Binder (1982) found that adult patients with right hemisphere lesions tended to have more details missing, whereas patients with left hemisphere lesions tended to have more fragmented details (i.e., details which are not drawn as a unit) (reported in Lezak, 1983). However, King (1981), in his study of 114 patients with brain dysfunction and 71 control subjects, demonstrated that neither laterality of lesion nor type of lesion affected the ROCFT total score. He did not analyze approach style or types of errors (King, 1981), raising the possibility that type or location of brain dysfunction may affect a patient's approach to the drawing rather than the total score obtained.

For example, Messerli, Seron, and Tissot (1979), in their study of adult patients with frontal lobe lesions, found a number of frequent errors (reported in Lezak, 1983). In order of descending frequency, these were perseverations (either resulting from a disorganized approach, or from

drawing excessive elements of a set), transformations of a detail into a more familiar figure (e.g., a circle with three dots is drawn as a face), and omissions (reported in Lezak, 1983). Pillon (1981) demonstrated that patients with frontal lesions tended to have difficulty planning their approach to copying the figure, whereas patients with parietal-occipital lobe lesions typically had trouble spatially organizing the figure (reported in Lezak, 1983).

Concluding remarks on the adult ROCFT literature

Thus, the total score, the organizational style, and the types of errors have provided valuable information in adult neuropsychological assessment. Specifically, the more details included and the better the approach style, the less the indication of brain dysfunction. In adults, as would be expected in a complex task, IQ, education, and age appear to affect ROCFT performance, indicating that such factors should be taken into account (Spreen and Strauss, 1991). The primary areas of difficulty with ROCFT literature are scoring issues. Namely, the original scoring procedures were not operationally defined, prompting a number of researchers to design their own scoring systems. This is particularly problematic since no research has been conducted to discern which of these scoring systems is most clinically valuable.

Use of the ROCFT with children

In a sample of 454 normal children aged 5 to 14, Waber and Holmes (1985) found that children's copies of the ROCFT

tend to increase in organization with age. More specifically, the youngest children tended to organize their drawings around only the vertical axis, older children typically organized their drawings around both the vertical and horizontal axes, and the oldest children tended to be able to organize their drawings around the vertical, horizontal, and diagonal axes (Waber & Holmes, 1985). Unfortunately, Waber and Holmes (1985) do not describe at what approximate ages such shifts in capacity typically occur, except to note that children 13 years old and older tend to have the most organized drawings. Despite this lack of age-related information, the general pattern of changes with age suggests an increasing ability to organize and integrate a variety of information.

Age and handedness, but not sex, significantly affected organization scores on children's ROCFT (Waber & Holmes, 1985). Karapetsas and Kantas (1991), in a sample of 420 right-handed 5 1/2 to 12 1/2 year old children in Crete, obtained similar results for age effects on ROCFT total scores. More specifically, 5 1/2 to 6 1/2 year old children performed significantly worse than all older children on ROCFT total scores, suggesting that a developmental shift occurs at around age 6 to 7 (Karapetsas & Kantas, 1991). In a sample of 514 left-handed children in Greece, Karapetsas and Vlachos (1992) obtained similar results: 5 1/2 to 6 1/2 year olds scored worse than all age groups over 7 1/2, and 6

1/2 to 9 1/2 year olds had significantly lower scores than all other age groups.

Although Waber & Holmes (1985) reported that sex does not affect how children approach the ROCFT, Karapetsas and Kantas (1991) and Karapetsas and Vlachos (1992) found that male children received significantly lower total scores than female children. Specifically, around age 8 1/2, right-handed female children began obtaining significantly higher scores on the ROCFT than did male children (Karapetsas & Kantas, 1991). In left-handed children, females significantly outscored males for the age range from 7 1/2 to 9 1/2, but were statistically equivalent in younger and older age ranges (Karapetsas & Vlachos, 1992). The contrasting results obtained by Waber and Holmes (1985) in Boston and Karapetsas and colleagues (1991, 1992) in Greece present two possibilities: (1) that, although a child's sex does not affect organization of the ROCFT, female children are able to accurately copy more details at certain ages; and (2) that cultural differences between Greece and the Northeastern United States account for the different findings.

In the only study comparing a normal sample with a clinical sample, Waber and Bernstein (1994) found that the organizational score (Waber & Holmes, 1985) was substantially greater for control versus learning disabled children. Waber and Bernstein (1994) noted that the learning disabled children's performance was significant for the lack of improvement with age. Because the normal

children's scores increased steadily with age, reliable differences between the two groups clearly emerged around 9 years of age (Waber & Bernstein, 1994).

Concluding remarks on the ROCFT's use with children

The relationship between demographic characteristics and the ROCFT appear to be different in children than in adults. Specifically, age and sex relate more strongly to ROCFT performance in children than in adults. Older children, particularly older female children, perform better on the ROCFT total score than younger children. This is in contrast to unreplicated HVOT data, which indicated that male children may perform better than the female children (Kirk, 1992). This pattern suggests that male children may be more skilled at mentally manipulating figures in space, but female children display greater ability to reproduce visual information through drawing. In any event, it is clear that age and sex are important components to keep in mind when employing the HVOT and the ROCFT in children.

Summary of the HVOT and ROCFT Research with Children

The HVOT and the ROCFT both display the potential for being quite useful in the neuropsychological assessment of children. Both the HVOT and the ROCFT assess visuospatial and visuomotor skills which are crucial to children's intellectual development. The HVOT and the ROCFT both display significant improvements in scores as children age, suggesting that the HVOT and the ROCFT may be able to detect

developmental changes in visuospatial and visuomotor tasks. Furthermore, since children have not begun to attain the adult ceiling level which is sometimes noted, the HVOT and the ROCFT may be particularly able to detect subtle deficits in children's visuospatial and visuomotor processes.

Problems with HVOT and ROCFT Literature with Children

Despite the promising results of the preliminary research previously outlined, much more research is necessary before forming conclusions about the utility of the HVOT and the ROCFT in children. For example, only three projects have evaluated either the HVOT or the ROCFT in neurologically impaired or learning disabled children (Seidel, 1994; Jackson & Culbertson, 1977; Waber & Bernstein, 1994). These studies provide promising but limited data for the use of the HVOT and the ROCFT with a clinical population. The remainder of the research with the HVOT and the ROCFT in children has focused upon normal children (Hilgert & Treloar, 1985; Karapetsas & Kantas, 1991; Kirk, 1992; Waber & Holmes, 1985; Waber & Holmes, 1986). Such research has provided valuable normative data (Karapetsas & Kantas, 1991; Kirk, 1992; Waber & Holmes, 1985), validity information (Hilgert & Treloar, 1985), and scoring criteria (Mings, 1987; Waber & Holmes, 1985; Waber & Holmes, 1986). These studies provide the necessary foundations for continuing to explore the utility of the HVOT and the ROCFT in neuropsychological assessment.

However, a number of questions must be answered before the HVOT and the ROCFT can be employed with strong confidence in a clinical population. For example, only Hilgert and Treloar (1985) have examined the effect of IQ on children's HVOT performance; no one has examined the relationship between IQ and the ROCFT in children. In addition, only Hilgert and Treloar (1985) and Seidel (1994) has compared the HVOT with other measures of visual-perceptual and visuomotor skills to examine construct validity; no one has performed such correlations with the ROCFT. Furthermore, the data on the HVOT's and the ROCFT's ability to discriminate between normal and neurologically impaired children has been fairly limited. This project attempts to provide data that compensates for these limitations.

Rationale for this Project

This research project addressed (1) the criterion validity of the HVOT and the ROCFT in terms of the ability to detect developmental changes in middle childhood, (2) the construct validity of the HVOT and the ROCFT by correlating them with other measures of visuospatial and visuomotor skills, and (3) the criterion validity of the HVOT and the ROCFT by exploring whether any differences exist among children with medically identified neurological impairment, children with learning disabilities, and normal children.

Despite the methodological problems inherent in a learning disabled sample (Durrant, 1994; Taylor, 1988a), the

addition of a learning disabled sample provided valuable additional information. Learning disabled children presumably have some neurological dysfunction that places them at an intermediate level between the normal sample and the neurologically impaired sample. Therefore, the learning disabled sample furnished a more rigorous test of the HVOT and ROCFT's ability to discriminate between normal and non-normal samples. In addition, learning disabled children's performance on the HVOT and the ROCFT was important to document because neuropsychological testing plays such an important role in identifying the specific difficulties learning disabled children experience (Rourke, 1994; Taylor, 1988a, 1988b). Rourke (1994) and Taylor (1988b) have noted the importance of thorough neuropsychological evaluation (including visuoperceptual, visuospatial, and visuomotor assessment) with learning disabled children in order to assist in diagnostic issues and treatment planning.

The measures employed in this project were selected to either provide important screening information, to assess demographic information, or to evaluate visuoperceptual or visuomotor skills. To screen for problems which might exclude a child from study, both estimated IQ and naming ability were assessed. IQ scores served 3 purposes: (1) to screen out children who did not meet certain IQ criteria; (2) to examine visuospatial and visuomotor skills while statistically controlling for general intellectual ability; and (3) to determine the association between IQ scores and

HVOT and ROCFT scores. Since naming ability is a prerequisite for the HVOT, it was also necessary to screen for naming deficits (Spreen & Strauss, 1991).

Other measures employed were intended to assess various aspects of visuomotor skills. For example, the Picture Completion (PC) subtest of the Wechsler Intelligence Scales for Children or the Wechsler Preschool and Primary Scales of Intelligence (Wechsler, 1974; Wechsler, 1989; Wechsler, 1991) requires visual skills similar to the HVOT and ROCFT: recognition of the item (HVOT) and visual analysis of details of the item (both HVOT and ROCFT). Similarly, the Object Assembly (OA) subtest of the Wechsler Intelligence Scales for Children is essentially similar to the HVOT, except that Object Assembly requires manual rather than mental manipulation of the parts of the object. Additionally, Beery's (1989) Test of Visual-Motor Integration (VMI) is a commonly used test of graphomotor ability, and is therefore similar to the ROCFT. These tests were employed to evaluate the construct validity of the HVOT and the ROCFT.

Hypotheses for this Project

The specific hypotheses included the following:

(1) All of the following dependent variables would be significantly associated with (a) age and (b) sex: (1) HVOT total score, (2) the number of HVOT isolate response errors, (3) the ROCFT total score, and (4) the ROCFT organizational score.

(2a) The HVOT total score would correlate significantly with IQ, Picture Completion, and Object Assembly.

(2b) Because the HVOT isolate response score probably relates to general abilities or executive functioning rather than to visuoperceptual or visuospatial skills per se, the HVOT isolate response score would correlate significantly with IQ.

(2c) The ROCFT total score would correlate significantly with IQ, Picture Completion, Object Assembly, and the Test of Visual-Motor Integration.

(2d) The ROCFT organizational score would correlate significantly with IQ (as with the HVOT isolate response score, the ROCFT organizational score probably relates more to general level of functioning and to executive systems rather than to visuoperceptual, visuospatial, or visuomotor abilities themselves).

(3) After controlling for any effects of age, IQ, and sex, the children with neurological impairment or with learning disabilities would display significantly more impaired performance than normal children on the following measures: (1) HVOT total score, (2) the number of HVOT isolate response errors, (3) the ROCFT total score, and (4) the ROCFT organizational score.

CHAPTER 2
METHOD

Subjects

Three samples were collected: a sample of neurologically impaired (NI) subjects, a sample of learning disabled (LD) subjects, and a sample of normal control (NC) subjects. In all three samples, children were aged 6 through 11. These ages were selected because, as described earlier, these are the ages in which children are developing visuomotor skills. At younger ages, children are insufficiently developed to participate fully in the tasks, and, at older ages, they have frequently come close to attaining adult scores. Therefore, this stage of late childhood was chosen as being the most instructive in evaluating the development of visuomotor skills.

Of the 56 NI subjects obtained through the files of Shands Hospital's Psychology Clinic who were in the appropriate age range and who had confirmed central nervous system disease, 10 were not eligible because their IQs were below the cutoff of 70. An IQ of 70 was selected as the cutoff score in order to balance the need, on the one hand, to have an NI sample that was fairly representative of the general NI population, with the needs, on the other hand, (1) to avoid inordinately skewing the results by having

severely impaired NI children, and (2) to avoid excessive IQ differences between samples.

All 5 children in this age range who met medical criteria for inclusion but received neither the HVOT nor the ROCFT had IQs below 70. These 5 children's ages (in years) were 8 (1 child), 9 (2 children), and 10 (2 children). Three of these children were female, 2 were male. Their diagnoses were epilepsy with history of viral meningitis, severe cortical atrophy secondary to anoxia, epilepsy and left hemiparesis secondary to focal encephalomalacia, cerebral palsy, and brain stem tumor.

In addition to the 10 children excluded because of IQ, two children were not eligible because they had received the HVOT only, and their confrontation naming scores were two standard deviations or more below the mean for their age or grade. Finally, 1 child's data was not employed because the raw data was not available in his file. Of the 43 children remaining, two children's HVOT scores were deleted because of low naming; however, their ROCFT and other scores were retained.

Fifty children obtained archivally through the Psychology Clinic and Pediatric Behavioral Neurology Clinic at Shands Hospital were the appropriate age and had been diagnosed as LD by a qualified pediatric neurologist or neuropsychologist. Of this sample, 16 children were ineligible because they received neither the HVOT nor the ROCFT. These children's diagnoses included dyslexia,

general language disability, visuospatial disability, language processing disability, and visuomotor disability, with 1 secondary diagnoses of spelling disability. Further demographic data on these 16 children is explored in the results section. In addition to these 16 children, 2 children were ineligible because of IQ scores below 80 (80 and 85 are standard IQ cutoffs for LD children). Because only 6 children in the LD sample had received the HVOT, the data for the HVOT within the LD sample was insufficient for statistical analysis. Therefore, the 3 children who had received only the HVOT were excluded, leaving 29 children in the final LD sample.

In the NC sample, 40 children were initially recruited. Six of these children were reported to be gifted on initial screening, and therefore did not receive testing. Eight additional children were found to have estimated IQs above 126, and were therefore excluded from data analysis (no child had an IQ below the lower cutoff of 75). One child did not receive testing because she had migraine headaches. Two children's HVOT scores were not analyzed because of low naming scores. Therefore, the NC final sample consisted of 23 children with all data available for analysis, and 2 children with ROCFT and other data appropriate for analysis.

Measures

In addition to the HVOT and the ROCFT, several other measures were employed to evaluate visuomotor and other

functions. An estimated IQ or Full-Scale IQ was obtained for each subject. The estimated IQs were based upon the Vocabulary and Block Design subtests of the Wechsler Intelligence Scale for Children-Revised (WISC-R) (Wechsler, 1974). Full-scale IQs were measured by the WISC-R or by the Wechsler Intelligence Scale for Children-III (WISC-III) (Wechsler, 1991) or the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R) (Wechsler, 1989). Because the ability to name pictures of objects is an important component of the HVOT, confrontation naming ability was screened using the Visual Naming subtest of the Multilingual Aphasia Exam (MAE) (Benton & Hamsher, 1989) or the Boston Naming Test (Goodglass, Kaplan, & Weintraub, 1978). The HVOT and the ROCFT require visual perception and visual analysis; these abilities were also evaluated employing the Picture Completion subtest of the WISC-R. Because the HVOT is intended to measure patients' ability to internally manipulate objects' positions in space, evaluation of the ability to physically reorganize parts of objects into meaningful wholes was explored using the Object Assembly subtest of the WISC-R. Finally, a measure of copying ability which is less complex than the ROCFT and is already widely used among children, Beery's (1989) Test of Visual-Motor Integration, was given to subjects.

Hooper Visual Organization Test (HVOT)

Since the HVOT was reviewed above, only administration information is provided here. For the HVOT, the directions given to normal children were, "This is a test of your ability to recognize pictures of objects when the pictures have been cut up and rearranged. Look at each picture and then decide what it might be if it were put together. For example, look at the first picture. What would it be if it were put together?" (Hooper Visual Organization Test manual, 1983). If the child said "Fish," the examiner responded "That's right. It's a fish. Now do the other pictures in the same way. Toward the end they become rather hard. Try to give an answer even if you are not sure of it" (Hooper Visual Organization Test manual, 1983). If the child did not say "Fish" on the first card, the examiner said, "The correct answer is 'fish.' You see, here is the head, the fins, and the tail. If it were put together correctly, it would be a fish. Now do the other pictures in the same way. Toward the end they become rather hard. Try to give an answer even if you are not sure of it" (Hooper Visual Organization Test manual, 1983).

In addition to the total raw score (determined according to the manual's scoring criteria), an isolate response score was computed. The following responses counted one point toward an isolate response score: "duck" or "goose" for item 1, "hoe" for item 11, "net" for item 12, "pencil" for item 14, "anvil" for item 18, "island" for item

21, "pipe" for item 22, "tray" for item 29, and "toilet plunger" for item 30 (Hooper Visual Organization Test manual, 1983; Lezak, 1983). These isolate responses were collected because little is known about children's tendencies to commit such errors.

Rey-Osterrieth Complex Figure Test (ROCFT)

Since the ROCFT was reviewed earlier, reliability and validity information are not repeated here. Prior to presenting the figure, the examiner gave normal children a 8 1/2 by 11 inch piece of white paper (presented horizontally) and said, "I am going to show you a complicated drawing. I would like you to draw it for me on this piece of paper. I will be giving you a new pencil from time to time. When I do that, please trade pencils with me, and continue working." The Rey-Osterrieth Complex Figure was then presented to each child horizontally, with the diamond to the child's right. The examiner timed the child's copy of the ROCFT, and provided the child with a new pencil when the child began working on a new section of the drawing. If a child did not receive the pencils in the predetermined order, the order was recorded on a separate sheet of paper.

The total score for the ROCFT was computed using Mings' (1987) version of Osterrieth's (1944) scoring. Mings (1987) provides operationalized criteria for judging the accuracy of a detail and its placement. The organizational level of

the ROCFT was determined using Waber and Holmes' (1985) scoring criteria.

Wechsler Intelligence Scale for Children-Revised (WISC-R) Estimated IQ (EIQ)

The Wechsler Intelligence Scale for Children-Revised (WISC-R) is an excellent measure of Verbal IQ, Performance IQ, and Full-Scale IQ (Spreen & Strauss, 1991; Vernon, 1984; Wechsler, 1974). However, because of its length, it was impractical to give the entire WISC-R to all of the normal children who were recruited. Therefore an Estimated IQ (EIQ) was obtained. The WISC-R was selected instead of its recent revision, the Wechsler Intelligence Scale for Children-III (WISC-III) because the majority of the clinical population and learning disabled children had received the WISC-R.

Fortunately, a fairly accurate estimate of the WISC-R IQ can be obtained by giving two subtests, Vocabulary and Block Design (Sattler, 1988; Spreen & Strauss, 1991). The Vocabulary subtest requires children to define verbally a number of words, and the Block Design subtest involves using red and white blocks to reproduce a red and white design presented to the child. These subtests were administered according to the WISC-R manual (Wechsler, 1974). Despite the potential for systematic differences between estimated IQs and IQs based on the entire WISC-R, the full WISC-R was employed for NI and LD children because of its enhanced accuracy over estimated IQ.

Vocabulary and Block Design have extremely high internal consistency ($r = .86$ and $r = .85$, respectively) and test-retest reliability ($r = .82$ and $r = .81$, respectively) (Wechsler, 1974). Furthermore, the combination of Vocabulary and Block Design has a higher validity coefficient (.906) than any other two WISC-R subtests (Sattler, 1988). Vocabulary correlates at .66, more than any other subtest, with the Verbal IQ score (Wechsler, 1974). Similarly, Block Design has the highest correlation with Performance IQ ($r = .66$) of all the subtests (Wechsler, 1974). Finally, the correlation between Full-Scale IQ and subtest scores is highest for Vocabulary ($.65 <= r <= .88$), Block Design ($.67 <= r <= .88$), and Picture Arrangement ($r = .67$) (Haynes, 1982; Ryan, 1981; Wechsler, 1974). Given these data, Vocabulary and Block Design provide the most accurate Estimated IQ that can be obtained from only two subtests.

A few of the children obtained through the Psychology Clinic (13 NI children) or the Pediatric Behavioral Neurology Clinic (3 LD children) received the WISC-III (Wechsler, 1991). Although the possibility of systematic differences between WISC-III Full-Scale IQ and WISC-R Estimated IQ poses problems, Vocabulary and Block Design for the WISC-III do correlate highly (.77 and .76, respectively) with the WISC-R (Wechsler, 1991). Because a WISC-III IQ score would be more valuable than no IQ at all, the WISC-III Full-Scale IQ scores were employed. However, the WISC-III Full-Scale IQ tends to be about 5 points less than the

WISC-R Full-Scale IQ (Wechsler, 1991). Although the differences between the Vocabulary-Block Design estimated IQs for the WISC-R and Full-Scale IQs for the WISC-III have not been evaluated, it is likely that the WISC-III Full-Scale IQs are also lower than the WISC-R estimated IQs. For accurate comparison among subjects, these scores required equalization. Because more children received the WISC-R, the WISC-R was used as the standard. Therefore, 5 points were added to all WISC-III IQs or estimated IQs.

One NI child and one LD child received the Wechsler Preschool and Primary Scale of Intelligence - Revised (WPPSI-R) (Wechsler, 1989). The WPPSI-R Full-Scale IQ correlates at .85 with the WISC-R; however, it yields scores about 7 points lower than the WISC-R. Seven points were therefore added to all WPPSI-R IQ scores.

Multilingual Aphasia Exam (MAE) Visual Naming (VN)

The Visual Naming (VN) subtest of the Multilingual Aphasia Exam (MAE) (Benton & Hamsher, 1989) requires the subject to name 30 pictures of objects (e.g., circle, piano, fork) or parts of objects (e.g., pedals, handle). For normal children, the examiner pointed to the picture (or part of the picture) and asked the child "What do you call this?" or "What is the name of this part?" (Benton & Hamsher, 1989). For adults, VN scores correlate highly with educational level, but do not correlate with age or sex (Benton & Hamsher, 1989). Furthermore, after controlling for educa-

tional level, VN scores tend to be lower for aphasic than for normal adult subjects: 18% of normal subjects receive scores of 48 or less, versus 90% of aphasic subjects obtaining scores of 48 or less (Benton & Hamsher, 1989). In children, VN scores increase with grade, and approach adult levels in 6th grade (Benton & Hamsher, 1989). Finally, in support of criterion validity, 46% of children with severe communication difficulties (dyslexia, stuttering, and expressive language disorders) obtained impaired scores on VN (Benton & Hamsher, 1989).

Boston Naming Test (BNT)

Some of the children collected archivally received the Boston Naming Test (Goodglass, Kaplan, & Weintraub, 1978) instead of the MAE VN subtest. The BNT requires the patient to name up to 60 line drawings of objects, and provides semantic and phonological cues when the patient is unable to spontaneously name the item. The BNT discriminates between dyslexic and normal readers (Cohen, Town, & Buff, 1988; Wolf & Obregon, 1992). Yeates (1994), in his review of the literature, noted that in all studies children's scores generally increased with age. Using composite norms from all five normative studies of the BNT in children, Yeates (1994) determined that, until 11 years of age, each 1-year age range received scores which were significantly larger than the scores of those children one year younger. Yeates' (1994) composite normative data were used to determine whe-

ther subjects fell within the normal range (defined as within 2 standard deviations of the mean) because of the increased accuracy and generalizability of the composite norms (especially compared to the norms from the small sample employed by Kaplan, Goodglass, and Weintraub (1983)).

Picture Completion (PC) Subtest of the WISC-R

In Picture Completion (PC), the examiner shows the child pictures with an important detail missing, and the child's task is to determine what is missing. PC was administered in accordance with the instructions in the WISC-R manual (Wechsler, 1974). PC has a split-half reliability of .77 and a test-retest reliability of .76, and correlates at .50 with Verbal IQ, .54 with Performance IQ, and .57 with Full-Scale IQ (Sattler, 1988; Wechsler, 1974). For those children who were given the WISC-III, the correlation between WISC-R and WISC-III PC scores is .57 (Wechsler, 1991).

Object Assembly (OA) Subtest of the WISC-R

In Object Assembly (OA), the examiner presents the child with pieces of a two-dimensional puzzle, which the child must put together to form a whole object. OA was administered according to the rules presented in the WISC-R manual (Wechsler, 1974). OA's split-half reliability is .70, and its test-retest reliability is .72 (Sattler, 1988; Wechsler, 1974). It correlates at .46 with Verbal IQ, .60 with Performance IQ, and .56 with Full-Scale IQ (Sattler,

1988; Wechsler, 1974). For those instances when a child received the WISC-III, the correlation between WISC-R and WISC-III OA scores is .58 (Wechsler, 1991).

Test of Visual-Motor Integration (VMI)

The VMI presents children with up to 24 geometric shapes to copy (Beery, 1989; Cosden, 1985; Sattler, 1988). The examiner gives the child the test booklet and a pencil without an eraser (Beery, 1989). For normal children, after opening the test booklet, the examiner pointed to the first item and said "Make one like that. Make yours right here"(Beery, 1989). The VMI is discontinued after three consecutive failures (Beery, 1989).

The median inter-rater reliability for the VMI is .93, with a range from .58 to .99 (Beery, 1989; Spreen & Strauss, 1991). Test-retest reliability ranges from .63 (7 month test-retest interval) to .92 (2 week test-retest interval), with a median test-retest reliability of .81 (Beery, 1989; Spreen & Strauss, 1991). The median split-half reliability coefficient is .78, with a range from .66 to .92 (Beery, 1989; Spreen & Strauss, 1991).

In support of the VMI's validity, the VMI correlates highly ($r = .89$) with chronological age, visual skills ($.72 <= r <= .80$), motor skills ($r = .76$), and other drawing tasks ($.36 <= r <= .79$) (Beery, 1989; Spreen & Strauss, 1991). It correlates mildly with intelligence ($.37 <= r <= .59$) and achievement (mean $r = .50$). In support of

obtained in order to estimate socioeconomic status. The ROCFTs and the VMIs were all rated by a master's level graduate student in clinical and health psychology.

Procedure for Subjects with Learning Disabilities

Subjects with learning disabilities had Full-Scale IQ scores of at least 80, no other neurological illness, and were deemed by an expert pediatric neurologist or pediatric neuropsychologist to have a learning disability. These subjects were obtained archivally from the Psychology Clinic and the Pediatric Behavioral Neurology Clinic at Shands Hospital in Gainesville, Florida. Their ROCFT and VMI protocols were scored by the graduate student who also scored the NI children's data.

Procedure for Normal Control Subjects

Community churches or church members who were contacted by phone or in person assisted in recruitment of normal children. An active member of each church solicited participants. Churches and parents were encouraged to participate by promising them, contingent upon parents' approval, donations in the amount of $4.00 per child as long as subjects are needed. Obviously, $4.00 per child is negligible, but participation of 25 children would result in a $100 donation, which is a sizeable amount.

In addition to these incentives to the church, children were provided an inexpensive reward, which they selected

from a box of appropriate gifts. Parents who wished to learn the results of their child's participation were provided with that information, with appropriate vagueness regarding the results of the IQ estimation ("Above Average" if the child obtained an estimated IQ greater than 115, "Average" if the child obtained an estimated IQ between 85 and 115, and "Below Average" along with any necessary recommendations if the child obtained an estimated IQ below 85).

Parents who were willing to participate were asked questions regarding their child (e.g., birthdate, sex, and any history of neurological impairment, learning disability, attention-deficit disorder, or giftedness) (see Appendix A for Telephone Screening Form). Once preliminary criteria were met, the project was explained as follows:

> We are trying to gather information that will assist us in helping children who have brain disorders. We want to gather information about several tests to see how useful they are in evaluating children with brain problems. In order to see how useful these tests are with children with brain problems, we need a group of normal children to compare them with. Your child would be in this group. If you want him/her to participate, _____ (child's name) will spend about an hour being asked some questions, and being asked to draw or put together some things. Most children find many of these tests fun to do. When _____ (child's name) is done, we will tell him/her what a great job _____ (child's name) did, and will allow him/her to select a small toy. We will be happy to provide you with information about the results of the testing. We are paying $4 for each child's participation. You will have the option of our paying you, paying your child, or making a donation to _____ _____(name of school or church the child was recruited from).

Any questions were answered honestly, with some vagueness about what the tests measure: "They measure a wide variety

of things--some of the questions will be about things your child may have learned in school, and some tasks will look at his/her ability to draw or build things."

If the parent was willing to participate, they were asked to provide information about the parental marital status, occupations, and educational levels, and about the child's race. They also decided whether they wished the $4 to be paid to them, to their child, or to the school or church from which they were recruited. After obtaining written informed consent, testing was performed at the child's home. All testing was performed by two Master's level graduate students in clinical and health psychology. Tests were administered in the following order: the ROCFT, the Vocabulary subtest of the WISC-R, the VN subtest of the MAE, the Picture Completion subtest of the WISC-R, the Block Design subtest of the WISC-R, the Object Assembly subtest of the WISC-R, and the VMI.

In order to examine inter-rater reliability, the NC sample's ROCFTs and VMIs, which have questionable inter-rater reliability data, were scored by two people, both Master's level graduate students in clinical and health psychology. Unfortunately, no rater was blind to condition, because of the necessity for patient's files to remain on clinic property. Other tests were rated by only one scorer, either because their reliability has been well-established (Vocabulary, Block Design, Picture Completion, Object

Assembly), or because their scoring is so well-defined that inter-rater differences are quite improbable (HVOT, VN).

CHAPTER 4
RESULTS

All statistical analyses were performed on SPSS/PC version 3.0.

Inter-Rater Reliabilities

Goal 1: To demonstrate adequate inter-rater reliability for Mings' (1987) scoring system for the ROCFT total score, Waber and Holmes' (1985) scoring system for the ROCFT organizational score, and for Beery's (1989) VMI.

To obtain inter-rater reliabilities for Mings' (1987) scoring system for the ROCFT total score, for Waber and Holmes' (1985) scoring system for the ROCFT organizational score, and for Beery's (1989) VMI, two-tailed Pearson product-moment correlations were calculated between the two raters who scored the NC sample's data (including the 8 children who were ultimately excluded because of IQ scores above 126). (Although one-tailed correlations could have reasonably been performed because of the high probability of a positive correlation, the more conservative two-tailed analyses were employed throughout all analyses because Type II errors were deemed preferable to Type I errors.) The results of the correlations between raters' scores, tabulated in Table 1, reveal excellent inter-rater reliability ($r = .9702$) for Mings' (1987) scoring system for

Table 1

Inter-Rater Reliabilities

	Rater 1		
Rater 2	ROCFT Total	ROCFT OS	VMI
ROCFT Total	.9702*		
ROCFT Organ.		.8983*	
VMI			.8531*

Note. N = 33. OS = Organizational Score. Inter-rater reliabilities based upon two-tailed Pearson product-moment correlations.
* $p < .001$.

the ROCFT, and adequate inter-rater reliability for the ROCFT organizational score ($r = .8983$) and for the VMI ($r = .8531$). Based on these inter-rater reliabilities, the data for the NI and LD sample were only rated by one rater, a Master's level graduate student in clinical and health psychology.

Because Pearson product-moment correlations provide little information about the actual degree of agreement between two raters, frequency of different levels of percentage of agreement are presented in Table 2. To obtain a calculation that was comparable across the three measures, the percentage of agreement was calculated for each subject by dividing the number of items which the raters agreed upon

by the total number of items (144 1/4 point items for the ROCFT total score, 5 1 point items for the ROCFT organizational score, and 24 items, with point values ranging from 1 to 4 points, for the VMI. Thus, a difference of 1 point on the 144 item ROCFT total score would provide 99% agreement, whereas a 1 point difference on the 5 point ROCFT organizational score would result in 80% agreement. In

Table 2

Frequency of Different Percentages of Agreement Between the Raters

	Test		
% Agreement	ROCFT Total	ROCFT OS	VMI
100%	0	23	5
95-99%	8	0	13
90-94%	14	0	7
85-89%	6	0	3
80-84%	2	7	4
70-79%	3	0	1
60-69%	0	3	0
0-59%	0	0	0

Note. N = 33. OS = Organizational Score. Percentage of agreement calculated by dividing the number of items agreed upon by the total number of items (144 for the ROCFT total score, 5 for the ROCFT organizational score, and 24 for the VMI).

order to provide a more accurate measure of true inter-rater agreement, the VMI percentage of agreement was determined by item rather than by points.

As illustrated in Table 2, the high inter-rater reliability according to Pearson correlations for Mings' (1987) scoring for the ROCFT total score results in most instances from high degree of agreement (especially given the number of items to be rated). In a few instances, however, the high inter-rater reliability according to Pearson correlations seems to result from disagreements "balancing out" on the total score. For example, if one rater deducts points from one item but gives full credit on another item, and the other rater's scores are reversed, the total score remains similar for the two raters.

The ROCFT organizational score's inter-rater reliability scores are highly affected by its low range of values. Thus, despite having the highest incidence of 100% agreements, the ROCFT organizational score also has the highest degree of 80% or less agreements.

Although the VMI is comparable to the ROCFT total score in terms of percentage of agreement, its inter-rater Pearson correlations are lower than those of the ROCFT total and organizational scores. This low correlational inter-rater reliability largely represents the VMI total score's greater sensitivity to single item disagreements. Single item disagreements exert a greater influence on the VMI than on the ROCFT total and organizational scores for two primary rea-

sons. First, because many items on the VMI are worth more than one point, such items have a greater impact on total score than items worth only one point (or 1/4 point, as in Mings' (1987) ROCFT total score). Secondly, because of the discontinuance criteria for the VMI (absent for the ROCFT scales), single-item disagreements may result in disagreement about discontinuance criteria. Thus, one rater may stop scoring because discontinuance criteria has been met, while the other rater continues to score subsequent items.

To resolve the protocols in which percentage of agreement was below 90%, a third rater (who had completed an internship in clinical psychology) rated each protocol. Each item that had resulted in discrepant scores between the first two raters was resolved using the third raters' scores, and the resultant total scores were employed for all subsequent data analysis.

Demographic Information

Goal 2: To describe the three samples in order to identify any differences that must be taken into account in statistical analyses and in interpretation.

Because Type II errors would be less problematic than Type I errors when comparing demographic information among and within the three samples, no Bonferonni adjustments were performed for these analyses.

As shown in Table 3, the samples consisted of a neurologically impaired (NI) sample of 43 children (15

female, 28 male), a learning disabled (LD) sample of 29 children (4 female, 25 male), and a normal control (NC) sample of 25 children (16 female, 9 male). Although a one-way analysis of variance revealed that the three samples were not significantly different in terms of age, ($F(2,94) = 1.35$, $p = .26$), the three samples were significantly different in terms of sex, $X^2(2, N = 97) = 16.3629$, $p = .0003$ (Table 3). Chi-squares of pairwise conditions revealed that all three samples differed from one another: the NI sample had a higher proportion of males to females than the NC sample, (Yates-corrected $X^2(1, N = 68) = 5.4028$, $p = .02010$), and both the NI and NC samples had a smaller proportion of males to females than the LD sample, with Yates-corrected $X^2(1, N = 62) = 4.85962$, $p = .0279$, for the NI sample, and Yates-corrected $X^2(1, N = 54) = 16.34359$, $p = .00005$, for the NC sample.

All three samples failed to correspond to general population norms, with minorities underrepresented (Table 3). Forty-one of the 43 NI children were white (2 African American children), 27 of the 29 LD children were white (with 1 African American child and 1 child of both white and African American race), and 24 of the 25 NC children were white (1 African American child, with 1 Oriental child excluded because of high IQ). A chi-square analysis comparing race (white versus non-white) across the three samples resulted in a Yates-corrected $X^2(2, N = 97) = .16891$, $p = .9190$.

Table 3

Demographic Information

	Groups					
	NI		LD		NC	
Demo. Char.	M/Ratio	N	M/Ratio	N	M/Ratio	N
Age (Mos.)[a]	103.5	43	109.0	29	100.3	25
S.D.	21.2		18.2		21.2	
Sex (M/F)[b]*	31/12	43	25/4	29	9/16	25
Race (W/NW)[c]	41/2	43	27/2	29	24/1	25
SES[d]*	38.5	32	46.8	29	51.8	
25						
S.D.	12.2		12.2		10.3	
IQ[e]*	95.5	43	103.8	29	111.6	25
S.D.	12.1		11.8		11.2	

Note. Demo. Char. = Demographic Characteristic; Mos. = Months; M/F = Male/Female ratio; W/NW = White/Nonwhite ratio; SES = socioeconomic status. Eleven NI children were missing data necessary for calculation of socioeconomic status.

[a] $F(2,97) = 1.35$, $p = .26$.

[b] $X^2(2, N = 97) = 16.3629$, $p = .0003$.

[c] $X^2(2, N = 97) = .16891$, $p = .9190$.

[d] $F(2,85) = 9.438$, $p = .0002$.

[e] $F(2,97) = 15.1529$, $p < .0001$.

* Variables upon which the samples were significantly different.

Socioeconomic status (according to Hollingshead's (1975) four factor index of social status) was also

different among the three groups according to a one-way analysis of variance, $F(2,85) = 9.438$, $p = .0002$ (Table 3). Two-tailed t-tests to further evaluate this difference indicated that the NI sample was significantly lower in socioeconomic status than the LD group ($t(61) = -2.69$, $p = .009$) and the NC group ($t(55) = -4.35$, $p < .001$). However, the difference in socioeconomic status between the LD sample and the NC sample was not statistically significant, $t(54) = 1.62$, $p = .112$.

Finally, the difference in IQ between groups was statistically significant on a one-way analysis of variance, $F(2,94) = 15.1529$, $p < .0001$ (Table 3). Two-tailed t-tests on IQ by pairwise conditions revealed that each group was significantly different from the other two groups. The NI sample's mean IQ was significantly lower than the LD sample, $t(71) = -2.96$, $p = .004$; the LD sample, in turn, displayed significantly lower IQ scores than the NC sample, $t(52) = 2.54$, $p = .014$. Thus, the greatest difference in IQ scores was between the NI sample, which received the lowest IQ scores, and the NC sample, which received the highest IQ scores, $t(66) = -5.43$, $p < .001$.

Further Descriptive Data for the NI Sample

Goal 2A: To examine potential demographic differences within the NI sample in order to make any necessary adjustments in statistical analyses or in interpretations.

As displayed in Table 4, the most common diagnoses within the NI group included epilepsy (13), hydrocephalus (10), astrocytoma (5), traumatic brain injuries (5), medulloblastoma (4), arteriovenous malformation (3), brain lesion NOS (3), spina bifida (2), subarachnoid cyst (2), Arnold-Chiari malformation (2), and brain tumor NOS (2). Other diagnoses consisted of one case each of cerebral palsy, craniopharyngioma, ganglioglioma, glioma, hematoma, meningioma, myelomeningocele, neurofibromatosis, and ventricular septal disease. In addition, 13 children had undergone tumor resection and/or shunting, and 3 children had received radiation therapy. Fifteen of the 43 children had multiple neurological diagnoses.

The mean number of months since diagnosis was 47.5 months, with a standard deviation of 41 months. The average number of months since diagnosis for 6-7 year olds was 36.6 (s.d. = 34.6), for 8-9 year olds was 47.8 (s.d. = 37.7), and for 10-11 year olds was 65.7 (s.d. = 51.8). These large standard deviations are primarily the result of the large number of children (27.5% of the sample) who had been diagnosed at or shortly after birth. Eighty percent of the sample had been diagnosed more than a year before their neuropsychological evaluations.

Two-tailed t-tests comparing the acute (less than or equal to 12 months since diagnosis) with the non-acute patients revealed that the acute sample was not significantly different in terms of age ($t(39) = -.54$, $p = .594$) or

Table 4

Diagnoses of the NI Sample

Diagnosis	Level of Diagnosis		
	Primary	Secondary	Tertiary
Epilepsy	7	6	
Hydrocephalus	3	5	2
Astrocytoma	5		
Traumatic Brain Injury	5		
Medulloblastoma	4		
Arteriovenous Malf.	3		
Brain Lesion NOS	1	2	
Spina Bifida	2		
Subarachnoid Cyst	2		
Arnold-Chiari Malf.	2		
Brain Tumor NOS	2		
Other Primary Diagnosis[a]	6		
Other Secondary Diagnosis[b]		2	

Note. NOS = Not Otherwise Specified.
[a] Other Primary Diagnosis includes one case each of cerebral palsy, craniopharyngioma, ganglioglioma, glioma, meningioma, neurofibromatosis, and ventricular septal disease.
[b] The category of Other Secondary Diagnosis includes one case of hematoma and one case of myelomeningocele.

race (Yates-corrected $X^2(2, N = 40) = .0000$, $p = 1.0000$) (Table 5). However, the acute patients were of significantly higher socioeconomic status ($t(30) = 2.11$, $p = .043$), higher IQ ($t(39) = 3.22$, $p = .003$), and tended to be male

Table 5

Demographic Data by Acuteness of Illness

	Acuteness of Illness		
Demo. Char.	Acute (<= 1 yr) (N=10)	Non-Acute (> 1 yr) (N=30)	p
Mean Age (Mos.)	100.2	105.4	.594[a]
SD	21.7	20.9	
Male/Female	2/8	12/18	.3817[b]
White/Nonwhite	10/0	28/2	1.0000[c]
Mean SES	45.2	35.5	.043[d]
SD	13.0	11.2	
Mean IQ	105.4	92.8	.003[e]
SD	12.0	10.5	

Note. Yr = Year; Demo. Char. = Demographic Characteristic. Mos. = Months; SES = socioeconomic status. One acute and 8 non-acute patients were missing data necessary for calculation of socioeconomic status.

[a] $t(39) = -.54$, $p = .594$.

[b] Fisher's exact test.

[c] Yates-corrected $X^2(2) = .0000$.

[d] $t(30) = 2.11$.

[e] $t(39) = 3.22$.

(ratio of 8 males to 2 females versus 19 to 12 in the non-acute sample; Fisher's exact test resulted in a $p < .00001$). They were also less likely to receive the ROCFT without also receiving the HVOT, $X^2(2, N = 40) = 8.29305$, $p = .01582$.

These differences probably reflect several factors. The acute patients' higher socioeconomic status probably relates to the fact that families with more resources are more likely to seek neuropsychological assistance early in the disease process. The higher IQ among the acute sample, although initially counterintuitive, reflects the fact that almost a third of the total NI sample had been diagnosed at or shortly after birth. In many instances, such illnesses are more severe (e.g., hydrocephalus versus a minor head injury) and interfere more with children's development. Finally, the difference in tests administered probably reflects the fact that the children with acute illness may have received more thorough evaluations, so that if a child was able to complete the more difficult ROCFT, they also received the HVOT.

Twenty-two of the children who were in the NI sample received both the HVOT and the ROCFT, 12 received the HVOT only, and 9 received the ROCFT only. Table 6 presents demographic data on these three sets of children. Socio-economic status and sex were the same for these 3 subsets of NI subjects according to a one-way analysis of variance ($F(2,29) = .0495$, $p = .9518$) and chi-square ($X^2(2, N = 43) = 1.9264$, $p = .3817$), respectively. They also displayed no

Table 6

Demographic Data by Tests Administered for NI Sample

	Tests Administered			
Demo. Char.	Both (N=22)	HVOT Only (N=12)	ROCFT Only (N=9)	p
Mean Age (Mos.)*	110.7	88.9	105.1	.0124[a]
SD	17.4	20.8	22.5	
Male/Female	15/7	6/6	7/2	.3817[b]
Race (W/NW)	22/0	11/1	8/1	.3187[c]
Mean SES	38.1	39.4	37.7	.9518[d]
SD	9.7	17.0	9.0	
Mean IQ	96.4	99.8	87.7	.0624[e]
SD	11.6	11.7	11.1	

Note. Demo. Char. = Demographic Characteristic; Mos. = Months; W/NW = White/Nonwhite; SES = socioeconomic status. Eleven subjects were missing data necessary for calculating socioeconomic status, and so analyses for SES were based on the 32 subjects with complete data.

[a] $F(2,40) = 4.9045$.
[b] $X^2(2, N = 43) = 1.9264$.
[c] $X^2(2, N = 43) = 2.2869$.
[d] $F(2,29) = .0495$.
[e] $F(2,40) = 2.9763$.

difference according to race, $X^2(2, N = 43) = 2.28692$, $p = .3187$. However, a one-way analysis of variance revealed the groups were significantly different in terms of age ($F(2,40) = 4.9045$, $p = .0124$). Furthermore, the difference in IQ

bordered upon statistical significance ($F(2,40) = 2.9763$, $p = .0624$).

To examine further the significant difference in age, two-tailed t-tests were performed and revealed that the children who received both the HVOT and the ROCFT were significantly older than children who received the HVOT only, $t(33) = 2.91$, $p = .006$. The difference in age between children who received both the HVOT and the ROCFT and those who received the ROCFT only was not statistically significant, $t(30) = .51$, $p = .613$. Similarly, children who received the HVOT only were not significantly different in age than those who received the ROCFT only, $t(20) = -1.70$, $p = .105$.

Although the one-way analysis of variance for IQ only bordered on statistical significance, further analyses were performed to determine whether any differences in IQ existed for children who received different testing protocols. According to two-tailed t-tests, the children who received only the HVOT had significantly higher IQs than the children who received only the ROCFT, $t(20) = 2.41$, $p = .026$. The other t-tests examining IQ for pairwise groups were nonsignificant: for the comparison of children who received both the HVOT and the ROCFT with children who received the HVOT only, $t(33) = -1.05$, $p = .303$; for the comparison of children who received both tests and the children who received the ROCFT only, $t(30) = 1.56$, $p = .130$.

The difference in age between children receiving both the HVOT and the ROCFT and children receiving the HVOT only

probably reflects the fact that older children tend to receive more tests because they have a better attention span and more endurance than younger children. The fact that, on average, children who receive the ROCFT and not the HVOT have significantly lower IQs probably reflects the ROCFT's sensitivity to a greater range of difficulties. Therefore, when only the ROCFT or the HVOT is selected, the ROCFT tends to be chosen because it can provide more meaningful information than the HVOT alone.

Further Descriptive Data for the LD Sample

Goal 2B: To examine potential demographic differences within the LD sample in order to make any necessary adjustments in statistical analysis or in interpretations.

The LD sample consisted largely of children with dyslexia (22), language disabilities NOS (9), written language disabilities (4), arithmetic disabilities (4) visuospatial disabilities (2), and spelling disabilities (2) (Table 7). Eleven children had multiple learning disabilities.

Twenty-six children from the Pediatric Behavioral Neurology Clinic and 6 children from the Psychology Clinic at Shands Hospital comprised the LD sample. These two samples did not differ in terms of age ($t(30) = -.89$, $p = .381$), sex (Yates-corrected $X^2(1, N = 32) = .1171$, $p = .76482$), race (Yates-corrected $X^2(1, N = 32) = .00000$, $p = 1.0000$), or socioeconomic status ($t(31) = -1.33$, $p = .195$),

Table 7

Diagnoses of the LD Sample

	Level of Diagnosis		
Diagnosis	Primary	Secondary	Tertiary
Dyslexia/Reading	22		
Language NOS	6	3	
Written Language		4	
Arithmetic			4
Visuospatial	2		
Spelling		2	
Short-Term Memory	1	1	
Sensory Processing	1		
Auditory Processing		1	

or IQ ($t(31) = -.03$, $p = .979$). Indeed, the only discernible difference between the Pediatric Behavioral Neurology sample and the Psychology Clinic sample was in tests administered ($X^2(2, N = 32) = 32$, $p < .00001$): 3 of the Psychology Clinic sample received the HVOT and the ROCFT and 3 received the HVOT only, whereas all 26 children in the Pediatric Neurology Clinic sample received the ROCFT only. Because the LD sample size for the HVOT data is so small, the LD sample will be omitted from analyses of the HVOT.

The 16 children collected through the Pediatric Behavioral Neurology Clinic who did not receive the ROCFT were not significantly different than those children who did receive the ROCFT in terms of age ($t(41) = 1.29$, $p = .203$), sex (Yates-corrected $X^2(1, N = 42) = .03409$, $p = .8535$), race (Yates-corrected $X^2(1, N = 42) = .00000$, $p = 1.00000$), or socioeconomic status ($t(41) = .01$, $p = .992$). However, those children who received the ROCFT had significantly lower IQs than those who did not ($M = 102.9$, $SD = 12.7$, for those children who received the ROCFT, $M = 111.7$, $SD = 12.2$, for those children who had not received the ROCFT, $t(41) = -2.24$, $p = .030$). As with the NI sample, this pattern probably reflects the fact that children with more difficulties are more likely to receive the ROCFT because of the richness of the clinical information the ROCFT can potentially provide.

Further Descriptive Data for the NC Sample

Goal 2C: To examine potential demographic differences within the NC sample in order to make any necessary adjustments in statistical analyses or in interpretations.

Of the NC sample, 13 children were collected in Gainesville, Florida, and 12 children were collected in central Connecticut (the greater Hartford area). Demographic data for these two subsets is presented in Table 8. The Gainesville sample was significantly older and came from families with higher socioeconomic status than the

Table 8

Demographic Data for Geographic Subsets of NC Sample

	Geographic Region		
Demo. Char.	Gainesville (N=13)	Connecticut (N=12)	p
Mean Age (Mos.)	109.2	90.7	.029[a]
SD	24.0	14.5	
Male/Female	6/7	3/9	.411[b]
Race (W/NW)	12/1	12/0	1.000[c]
Mean SES	56.4	46.8	.021[d]
SD	6.9	11.4	
Mean IQ	111.2	112.0	.854[e]
SD	12.7	9.6	

Note. Demo. Char. = Demographic Characteristics; Mos. = Months; W/NW = White/Nonwhite; SES = socioeconomic status.
[a] $t(19.95) = 2.35$.
[b] Fisher's two-tailed exact test.
[c] Yates-corrected $X^2(1, N = 25) = .0000$.
[d] $t(17.84) = 2.54$.
[e] $t(23) = -.19$.

Connecticut sample, with two-tailed t-test results of $t(19.95) = 2.35$, $p = .029$ for age (using separate variance),and $t(17.84) = 2.54$, $p = .021$ for socioeconomic status (using separate variance). The two samples were not significantly different in terms of IQ ($t(23) = -.19$, $p =$

.854), race (Yates-corrected $X^2(1, N = 25) = .0000$, $p = 1.000$) or sex (Yates-corrected $X^2(1, N = 25) = .46769$, $p = .4941$.

Screening of Data

Goal 3: To examine the data for any violations of assumptions for planned statistical analyses, and to make any appropriate changes in the data or in planned analyses.

Missing data, a substantial disadvantage in archival research, existed in many instances for the NI and LD sample. Missing data for the dependent variables (the HVOT or the ROCFT) has already been described for the NI and LD samples. In the NI sample, children who were younger tended not to receive the ROCFT, and NI children with lower IQs tended to receive the ROCFT but not the HVOT. In the LD sample, tests administered depended on the site: all 6 HVOTs in the LD sample were from children evaluated in the Psychology Clinic, and 26 of the 29 ROCFTs were from children examined in the Pediatric Neurology Clinic. Because (1) missing data were nonrandom for the dependent variables, and (2) dependent variables were too important to risk creating misleading data by estimating values, analyses were performed with available data. However, some variations in planned statistical procedures were required. The LD sample was excluded from all HVOT analyses because the sample size for HVOT data in the LD sample was too low ($N = 6$). In addition, it was impossible to include both

HVOT variables and ROCFT variables in a multivariate analysis of covariance because too few subjects had received both measures. Thus, one analysis of covariance each was performed on HVOT data and on the ROCFT total score. As described below, the HVOT isolate response score and the ROCFT organizational score could not be analyzed with parametric statistical analyses because of failure to meet the assumption of normal distributions.

Demographic data or data on independent variables such as IQ subscales or the VMI were also missing from the NI and LD samples. In particular, information necessary for calculation of socioeconomic status was unavailable for several number of children. Some of the IQ subscales were also missing from several NI children (whose files had been transferred to the warehouse before Vocabulary and Block Design were retrieved, or, in a couple of instances, who had received short versions of IQ tests) and about half of the LD children (for whom the Full-Scale IQ, but not the subscale scores, were frequently reported). In addition, only about two-thirds of the NI sample and half of the LD sample received the VMI. Because these data were primarily for correlational analyses and were not necessary to other statistical analyses (e.g., were not used as a covariate), the correlations were simply performed on available data.

After examining frequency histograms, bivariate scatterplots, plots of residuals, and statistics for kurtosis and skewness, it was clear that the HVOT isolate

response score and the ROCFT organizational score were not normally distributed. Kurtosis and skewness were -.138 and .906, respectively, for the HVOT isolate response score, and .214 and 1.145, respectively, for the ROCFT organizational score. Although these scores are within the acceptable to borderline acceptable range, the lowest possible score was overrepresented on frequency histograms and the low range and integer nature of the data resulted in non-linear bivariate plots and plots of residuals. Neither a logarithmic transformation nor converting to the inverse value, both recommended by Tabachnick and Fidell (1989), was able to correct these problems. Therefore, whenever possible, nonparametric analyses (such as the Mann-Whitney test or Kruskal-Wallis) were performed on these variables. However, when parametric tests are the only option (as in correlations), the results must be interpreted with caution.

The other dependent variables were normally distributed according to frequency histograms, data for kurtosis and skewness, and plots of residuals. No obvious outliers were discerned, and all subjects' scores for dependent variables were within 2 standard deviations of the mean for their age and condition (NI, LD, or NC). Evaluations of Mahalanobis' distance indicated that no multivariate outliers required deletion (criteria for deletion for Mahalanobis' distance is $p <= .001$, and p for these data was consistently $> .05$). Thus, no outliers were removed from the general database.

Bonferonni Adjustments

Because of the number of planned analyses and consequent increased risk of Type I errors, a Bonferonni adjustment was calculated as follows. The first step in the Bonferonni adjustment was to adjust for the fact that 2 primary dependent variables (HVOT scores and ROCFT scores) exist; therefore, dividing $p = .05$ by 2, $p = .025$. Second, to adjust for the number of analyses for which probabilities would be calculated (analysis of effect of age, analysis of effect of sex, and analysis of effect of condition), $p = .025$ was divided by 3, resulting in a $p = .0083$.

Obviously, further divisions could be performed (e.g., using 4 dependent variables rather than 2). Because Bonferonni adjustments tend to be overly strict (thereby increasing the likelihood of Type II errors), this particular Bonferonni adjustment was selected in an attempt to minimize both Type I and Type II errors.

Relationships Between Dependent Variables and Age

Hypothesis 1a: The criterion validity of the HVOT and the ROCFT would be supported by data demonstrating that scores increase with age, thereby indicating the HVOT and ROCFT are valid as measures of developmental changes for children in this age range.

To examine for effects of age on the four dependent variables, analyses of variance were performed for the HVOT total score and ROCFT total score by age range. In

addition, a Mann-Whitney test and a Kruskal-Wallis test were performed, respectively, on the HVOT isolate response score and ROCFT organizational score according to age range. The analyses of variance for the HVOT total score was significant at below the .001 level, $F(2,52) = 12.016$, $p < .001$ (Table 9). T-tests to compare the age ranges for the HVOT total score revealed that the youngest age range was significantly different from the other two: 6-7 year olds obtained lower scores than 8-9 year olds ($t(42.86) = -3.94$, $p < .001$, using separate variance) and 10-11 year olds ($t(41) = -4.12$, $p < .001$). However, 8-9 year olds were not significantly different on the HVOT total score than 10-11 year olds ($t(24.09) = -1.21$, $p = .237$, using separate variance). This pattern remained consistent when individual samples were analyzed separately. A Kruskal-Wallis analysis for the HVOT isolate response score by age range was nonsignificant, $X^2(N = 55) = 5.2059$, $p = .0741$ (Table 9).

Like the HVOT total score, the analysis of variance for the ROCFT total score by age range was significant, $F(2,82) = 14.6065$, $p < .0001$ (Table 10). The youngest age range, 6-7 year olds, scored significantly lower than the middle age range, 8-9 year olds, $t(57) = -3.47$, $p = .001$) and than the oldest children, $t(51) = -5.35$, $p < .001$). With the Bonferonni adjustment, the 8-9 year olds did not obtain significantly lower scores than the 10-11 year olds, $t(56) = -2.04$, $p = .046$. These results were verified for the NC

Table 9

HVOT Scores by Age and Condition

	Condition					
	NI			NC		
Age Range	M	SD	N	M	SD	N
HVOT Total						
Age 6-7	20.1	3.5	14	20.6	3.2	11
Age 8-9	23.0	2.3	10	24.3	1.8	5
Age 10-11	24.2	3.7	8	24.9	3.1	7
Combined	22.5	3.5	32	22.7	3.5	23
HVOT IR						
Age 6-7	.93	.92	14	1.09	.83	11
Age 8-9	.90	1.10	10	.20	.45	5
Age 10-11	.38	.74	8	.29	.49	7
Combined	.78	.94	32	.65	.78	23

Note. IR = isolate response. $F(2,52) = 12.016$, $p = .000$, for the effect of age range on HVOT total score. Kruskal-Wallis $X^2(N = 55) = 5.2059$, $p = .0741$, for the differences by age range on the HVOT isolate response score.

sample. The NI sample and LD sample did not display significant differences between age ranges.

A Kruskal-Wallis analysis to examine ROCFT organizational score by age range was significant, $X^2(N = 85) =$

Table 10

ROCFT Scores by Age and Condition

	Condition								
	NI			LD			NC		
Age Range	M	SD	N	M	SD	N	M	SD	N
ROCFT Total									
Age 6-7	14.5	8.0	10	16.3	11.2	5	17.0	7.4	12
Age 8-9	20.2	8.5	12	22.9	6.5	15	30.9	4.1	5
Age 10-1	22.4	7.3	9	28.1	7.1	9	31.4	2.8	8
Combined	19.0	8.4	31	23.4	8.3	29	24.4	9.1	25
ROCFT OS									
Age 6-7	1.40	.84	10	1.40	.55	5	1.08	.29	12
Age 8-9	1.50	.80	12	1.93	1.22	15	3.00	1.58	5
Age 10-11	1.56	.73	9	3.22	1.56	9	2.62	1.19	8
Combined	1.48	.77	31	2.24	1.41	29	2.20	1.44	25

Note. OS = organizational score. $F(2,82) = 14.6065$, $p < .0001$, for the effect of age range on ROCFT total score. Kruskal-Wallis $X^2(N = 85) = 12.0017$, $p = .0025$, for the difference according to age range for the ROCFT organizational score.

12.0017, p = .0025 (Table 10). Examination of pairwise age ranges for the total sample using the Mann-Whitney test

revealed that the youngest age range obtained significantly lower scores on the ROCFT organizational score than the 10-11 year olds, $Z(N = 52) = -3.8264$, $p = .0001$. The difference between 6-7 year olds and 8-9 year olds approached significance, $Z(N = 59) = -2.4548$, $p = .0141$. However, 8-9 year olds did not significantly differ from 10-11 year olds on the ROCFT organizational score, $Z(N = 57) = -1.0055$, $p = .1084$. The NC sample's results paralleled the results for the combined sample. The NI sample only differed from the pattern of the combined sample and the NC sample insofar as the 6-7 year olds were not significantly different from the 10-11 year olds, $Z(N = 19) = -1.7562$, $p = .0791$. The LD sample's pattern differed from the NC sample insofar as the difference between 8-9 year olds and 10-11 year olds (age ranges that were not significantly different in the other samples) approached significance, $Z(N = 24) = -2.3329$, $p = .0197$. The difference between 6-7 year old and 10-11 year old LD children also approached significance, $Z(N = 14) = -2.4928$, $p = .0127$.

Relationships Between Dependent Variables and Sex

Hypothesis 1b: As reported in previous literature, scores on the HVOT and the ROCFT would vary depending on sex.

Two-tailed t-tests to examine differences according to sex on the HVOT and the ROCFT total scores were nonsignificant: for the HVOT total score, $t(54) = -.45$, $p =$

Table 11

HVOT and ROCFT Scores by Condition by Sex

	Condition								
	NI			LD			NC		
Test	M	SD	N	M	SD	N	M	SD	N
HVOT total									
Males	21.9	3.6	20		N/A		24.3	3.1	8
Females	22.3	3.7	12		N/A		21.9	3.5	15
HVOT IR									
Males	.800	.95	20		N/A		.50	.76	8
Females	.750	.97	12		N/A		.73	.80	15
ROCFT total									
Males	19.4	7.5	22	24.2	8.0	25	27.4	7.1	9
Females	18.1	10.8	9	18.0	9.6	4	22.7	9.8	16
ROCFT OS									
Males	1.4	.73	22	2.3	1.5	25	2.0	1.1	9
Females	1.7	.87	9	1.8	.96	4	1.9	1.4	16

Note. IR = Isolate Response; OS = Organizational Score.

.665; for the ROCFT total score, $t(84) = -1.11$, $p = .268$. Mann-Whitney tests for the HVOT isolate response score and the ROCFT organizational score were likewise nonsignificant,

$Z(N = 55) = -.3714$, $p = .7104$, for the HVOT isolate response score, and $Z(N = 85) = -.3223$, $p = .7472$, for the ROCFT organizational score.

Correlational Analyses

Hypothesis 2: The construct validity of the HVOT and the ROCFT would receive support, with specific anticipated correlations as follows: a) positive correlations between HVOT total score and IQ, Block Design (BD), Picture Completion (PC), and Object Assembly (OA), but not the VMI; b) negative correlation between the HVOT isolate response errors and IQ; c) positive correlations between the ROCFT total score and IQ, PC, OA, and the VMI; and d) positive correlations between the ROCFT organizational score and IQ.

Two-tailed Pearson product-moment correlations were performed between the raw scores for the dependent variables (HVOT total score, HVOT isolate response score, ROCFT total score, and ROCFT raw score) and the scaled scores for independent variables (Vocabulary, Block Design, IQ, Picture Completion, Object Assembly, and the VMI). Correlational results were determined by each condition to examine any differences between conditions in correlational patterns. In addition, because of the increased power provided through use of the combined sample, correlations were determined for the combined sample as well. In instances when the samples' correlations are substantially different for a given variable, such combined correlations will be less for the

combined sample; however, correlations which are stable regardless of condition will be strengthened in the combined sample correlations.

No Bonferonni adjustment was performed for the correlational analyses because the magnitude of the correlation is more important than the probability (Hays, 1963). However, interpretation of the correlational results must take into account the high number of correlations involved and the consequent increased risk of Type 1 error. To reduce this risk, a sufficient magnitude was determined to be r = .40, identified as the correlation necessary to conclude a "substantial relationship" (Thorndike, 1978, p. 50). Because probability data is of interest, probabilities below .05 are reported in addition to magnitude.

Correlational results for the HVOT total score and the HVOT isolate response score are reported in Table 12 (as indicated earlier, the LD sample was not employed in any HVOT analyses because of insufficient sample size for HVOT data). The HVOT total score displayed sizeable positive correlations with IQ (r = .42) and Object Assembly (r = .52) for the NI sample, but no sizeable correlations in the NC sample. The combined sample's only significant correlation with the HVOT total score was Object Assembly (r = .43). The HVOT isolate response score was significantly negatively correlated with Block Design for the NI sample only (r = -.69).

Table 12

Correlations Between the HVOT and Other Variables

	Condition					
	NI		NC		Combined	
Variable	r	N	r	N	r	N
HVOT Total Score						
Vocabulary	.11	17	-.06	23	.09	40
Block Design	.31	18	.37	23	.37[a]	41
IQ	.42*[a]	32	.24	23	.34[a]	55
Picture Compl.	.31	32	-.07	23	.28[a]	55
Object Assembly	.52*[c]	32	-.02	23	.43*[c]	54
VMI	.20	30	.01	23	.13	53
HVOT IR						
Vocabulary	.35	17	-.14	23	.07	46
Block Design	-.69*[c]	18	-.27	23	-.33	47
IQ	.23	32	-.28	23	-.05	61
Picture Compl.	.23	32	-.14	23	.01	61
Object Assembly	-.13	31	-.03	23	-.16	60
VMI	-.12	30	-.19	23	-.12	59

Note. IR = Isolate Response.
* r >= .40.
[a] p < .05.
[b] p < .01.
[c] p < .0083.

The correlations for all three conditions for the ROCFT total score and the ROCFT organizational score are displayed in Tables 13, with results for the combined sample in Table 14. For both the NI and LD samples, the ROCFT total score was significantly correlated with Object Assembly ($r = .51$ for the NI sample, $r = .53$ for the LD sample) and the VMI ($r = .59$ for the NI sample, $r = .55$ for the LD sample). In addition, the ROCFT total score was significantly correlated with IQ ($r = .48$) for the NI sample only. The ROCFT total score did not correlate significantly with any variable for the NC sample; however, for the combined sample, the ROCFT total score displayed a sizeable correlation with the VMI ($r = .46$).

The ROCFT organizational score was highly correlated with Object Assembly ($r = .40$) for the NI sample, and with Picture Completion ($r = .52$) and Object Assembly ($r = .57$) for the LD sample. As with the ROCFT total score, it displayed no sizeable correlations with any independent variables for the NC sample. Probably as a result of these inconsistent correlations across samples, the correlations for the combined sample did not correspond to the results of the NI and LD samples ($r = .20$ for Object Assembly).

In addition, the ROCFT total score and the ROCFT organizational score were significantly correlated at .688, $N = 85$, $p < .001$.

Table 13

Correlations Between the ROCFT and Other Variables

	Condition					
	NI		LD		NC	
Variable	r	N	r	N	r	N
ROCFT Total Score						
Vocabulary	-.18	15	.10	14	.15	25
Block Design	.28	15	.38	14	.06	25
IQ	.48*[b]	30	.12	26	.12	25
Picture Compl.	.08	30	.21	17	-.11	25
Object Assembly	.51*[b]	30	.53*[a]	17	-.05	25
VMI	.59*[b]	27	.55*[a]	15	.14	25
ROCFT OS						
Vocabulary	-.10	16	.31	15	.05	25
Block Design	.38	16	.28	15	.10	25
IQ	.26	31	.20	29	.09	25
Picture Compl.	-.13	31	.52*[a]	19	-.07	25
Object Assembly	.40*[b]	31	.57*[a]	18	.03	25
VMI	.31	28	.34	15	.07	25

Note. OS = Organizational Score.
* r >= .40.
[a] p < .05.
[b] p < .0083.

Table 14

Correlations Between the ROCFT and Other Variables for Combined Sample

	ROCFT Score			
	Total Score		Organizational Score	
Variable	r	N	r	N
Vocabulary	.19	56	.20	56
Block Design	.32[a]	56	.26	56
IQ	.33[b]	85	.24[a]	85
Picture Compl.	.20	75	.08	75
Object Assembly	.34[b]	74	.20	74
VMI	.46*[b]	68	.25[a]	68

* r >= .40.
[a] p < .05.
[b] p < .0083.

Determination of Covariates

Goal 3: To determine whether any covariates were necessary for the next step of data analysis, the comparison (via analyses of variance or covariance) of the three samples' performance on the HVOT total score and ROCFT total score. (The HVOT isolate response score and the ROCFT organizational score did not receive these analyses because of their failure to meet the assumption of normality.)

Hierarchical multiple regression was employed to determine appropriate covariates for multivariate analyses of covariance. Because Type I errors are more problematic than Type II errors in determination of covariates, the multiple regression equations were performed without using the Bonferonni adjustments in order to determine whether a variable's contribution was significant. A hierarchical multiple regression was performed for each of the dependent variables which met the assumptions for analyses of variance (i.e., the HVOT total score and ROCFT total score). The first block entered into each equation was age, IQ, sex, and socioeconomic status. These variables were selected either because they were expected to significantly affect the dependent variable (e.g., since raw scores were being used, age should account for some of the variance), or because the three samples differed on that variable (e.g., sex, IQ, and socioeconomic status). If the first block of variables accounted for a significant proportion of variance, the variables were examined more closely to determine which variables accounted for the most variance. Variables were then entered sequentially, with variables accounting individually for the most variance entered first. If a variable did not significantly increase the amount of variance accounted for, it was deleted from the multiple regression equation.

The results of the first block of variables for the multiple regression equation indicated that age and IQ

accounted for significant proportions of the variance for both dependent variables. In addition, socioeconomic status emerged as a significant covariate for the ROCFT total score.

The second block entered into the multiple regression equation was a set of interaction terms for age by IQ, age by sex, age by socioeconomic status, IQ by sex, IQ by socioeconomic status, and sex by socioeconomic status. These interaction terms were not significant for any of the dependent variables. The third block, 3-way interaction terms (age by IQ by sex, age by IQ by socioeconomic status, age by sex by socioeconomic status, IQ by sex by socioeconomic status), also did not account for a statistically significant proportion of the variance in either of the multiple regression equations and these interaction terms were therefore deleted. Finally, the 4-way interaction term, age by IQ by sex by socioeconomic status, was entered, and results indicated that no significant variance was accounted for by the 4-way interaction.

Next, the selected covariates were checked for normality, linearity with the dependent variable, and homogeneity of regression. Because socioeconomic status did not display homogeneity of regression (i.e., bivariate scatterplots of the ROCFT total score with socioeconomic status revealed that the slope was substantially different for the different samples), it violated the assumptions of

the analysis of covariance and therefore was not employed as a covariate.

Group Comparisons

Hypothesis 3: After controlling for age and other variables, the HVOT and the ROCFT will be significantly different across samples, with the lowest scores obtained by the NI sample, the middle scores by the LD sample, and the highest scores for the NC sample. Such a finding would support the criterion validity of the HVOT and the ROCFT in terms of ability to discriminate between neurologically impaired and normal children after other discriminating variables have been controlled.

Because more than half of the subjects were missing either the HVOT or the ROCFT, separate analyses of covariance were employed for the HVOT total score and the ROCFT total score. The analyses of covariance for the HVOT total and ROCFT total scores employed age and IQ as covariates. Because so few LD children received the HVOT, the LD sample was not included in the HVOT analyses. The results of these analyses of covariance indicated that any differences between samples was not robust enough to account for significantly more variance than the covariates: $F(1,51) = .204$, $p = .653$, for the effect of condition on the HVOT total score (refer to Table 9), and $F(2,80) = 2.347$, $p = .102$, for the effect of condition on the ROCFT total score (refer to Table 10).

A Mann-Whitney test and a Kruskal-Wallis test were performed on the HVOT isolate response score and the ROCFT organizational score, respectively, because these variables did not meet the assumptions for analyses of variance. The Mann-Whitney for HVOT isolate response score for the NI and NC samples was nonsignificant, $Z(N = 55) = -.3446$, $p = .7304$ (refer to Table 9). The Kruskal-Wallis to compare samples on the ROCFT organizational score was also nonsignificant, $X^2(N = 85) = 5.1266$, $p = .0771$ (refer to Table 10).

Discriminant Analysis

Because of the clinical relevance of employing test data to clarify diagnostic issues, a discriminant function analysis was performed to determine to what extent the HVOT and ROCFT total scores can predict whether children are NI or NC. It was impossible to include the LD sample in this analysis because of the amount of missing data for the HVOT in the LD sample. Using only the two normally distributed HVOT and ROCFT scores as independent variables and entering mean values to classify cases with missing data, prediction to the NI group was 48.8% accurate and prediction to the NC group was 76.0% accurate. This was not statistically significant, with the HVOT yielding $F(1,41) = .1112$, $p = .7404$, and the ROCFT resulting in $F(1,41) = 1.202$, $p = .2677$. Thus, for this sample, neither the HVOT nor the ROCFT was able to reliably predict whether a child is NI or NC.

Had sample size and available data permitted, differences within the NI sample or within the LD sample would have been performed to evaluate differences according to diagnosis or location of lesion. However, both samples were too heterogeneous for such analyses, and classifications according to diagnosis or location of lesion resulted in sample sizes that were too small for meaningful statistical analysis.

Post Hoc Analyses

As post hoc analyses, further evaluation of correlational data and of differences among groups was performed. In order to explore the construct validity data while controlling for IQ, partial correlations were performed. For the HVOT total score, these partial correlations differed substantially from the Pearson correlations in several instances. For the NI sample and the combined sample, the high correlation for Object Assembly was largely attributable to IQ (partial $r = .17$ versus $r = .52$, for the NI sample; partial $r = .18$ versus $r = .43$, for the combined sample). In addition, the NC sample displayed a high correlation between the HVOT total and the VMI (partial $r = .46$ versus $r = .01$).

For the Hooper isolate response score, partial correlations controlling for IQ generally corresponded to the Pearson correlations, with the exception of a high

correlation with the VMI for the NC sample only (partial r = .42 versus r = -.19).

For the ROCFT total score, controlling IQ through partial correlations resulted in several differences from Pearson correlation results. Within the NI sample, the partial correlation for Picture Completion was of sufficient magnitude to be deemed meaningful (partial r = .47 versus r = .08). Within the LD sample only, IQ accounted for the substantial Pearson correlation between ROCFT total and Object Assembly: the partial correlation was r = .01 versus r = .53. Similarly, the partial correlation between the ROCFT total score and the VMI was less than the Pearson correlation (partial r = .34 versus r = .59). In contrast, the LD and NC samples displayed greater partial correlations than Pearson correlations between the ROCFT total and the VMI: partial r = .93 versus r = .55 for the LD sample, and partial r = .66 versus r = .14 for the NC sample). Correlational ROCFT total score results for the combined sample were not substantially different from Pearson correlations when IQ was controlled through use of partial correlations.

The ROCFT organizational score partial correlational results were different in several respects from Pearson correlational results. For the NI sample, the Pearson correlation with Object Assembly was largely accounted for by IQ: the partial correlation was .22 versus the Pearson correlation of .40. For the LD, NC, and combined samples,

the ROCFT organizational score displayed substantial correlations with the VMI ($r = .60$ rather than .34 for the LD sample; $r = .51$ rather than .07 for the NC sample; and $r = .45$ rather than .25 for the combined sample).

The remainder of post hoc analyses explored differences in HVOT and ROCFT scores among the three samples. First, because of the predicted (and confirmed by the data) correlation between outcome variables and IQ, the failure to find significant results when controlling for IQ was not surprising. IQ was included in order to determine whether the HVOT and the ROCFT provided data in addition to information about general level of functioning. Whether the groups were different on the ROCFT and the HVOT, without controlling for IQ, was also of interest in terms of examining criterion validity (i.e., whether the samples obtained different scores on the HVOT and the ROCFT). Therefore, analyses of covariance were repeated without IQ as a covariate, but with age as a covariate. For the HVOT total score, this analysis of covariance was nonsignificant, $F(1,52) = 1.502$, $p = .226$ (refer to Table 9). However, the ROCFT analysis of covariance was significant, $F(2,81) = 8.160$, $p = .001$ (refer to Table 10).

Further comparison of this significant difference among groups for the ROCFT total score revealed that the only clearly significant difference between groups was between the NI and NC samples, $F(1,53) = 17.439$, $p < .001$. However, the differences between all samples were significant at the

.05 level, with $F(1,51) = 4.171$, $p = .046$, for the LD versus NC sample, and $F(1,57) = 4.551$, $p = .037$, for the NI versus LD sample.

Because of the concern that the differences between the NI and NC sample were attributable to differences in socioeconomic status (which was confounded with group and had accounted for a significant amount of variance in the multiple regression equation), an attempt was made to analyze a subset of the samples that were comparable on socioeconomic status. However, any elimination of subjects with high and low socioeconomic status that succeeded in equalizing the samples resulted in such low sample sizes that statistical analyses was deemed inappropriate.

Another set of post hoc analyses attempted to diminish the variance accounted for by age in the multiple regression equations and analyses of covariance. The HVOT total score was translated to scaled scores using Kirk's (1992) norms, and z-scores were computed by age range to obtain age-corrected scores for the HVOT isolate response score, ROCFT total score, and ROCFT organizational score. Analyses of variance and nonparametric tests were repeated using these scaled or z-scores.

The multiple regression equations for the HVOT scaled score for the total score and ROCFT z-score for the total score revealed that age no longer accounted for a significant proportion of the variance, although it approached significance at the .05 level for the HVOT total

score, $F = 3.679$, $p = .0608$. A two-tailed t-test comparing HVOT total scaled score for the NI and NC samples was not statistically significant, $t(53) = -.81$, $p = .423$. However, the one-way analysis of variance (without covariates) for the ROCFT age-corrected z-scores resulted in a significant $F(2,82) = 5.790$, $p = .0040$. (Since differences in ROCFT total scores among samples were reviewed above, they were not repeated here.)

Differences between the NI and NC sample on z-scores for the HVOT isolate response score were nonsignificant on a Mann-Whitney, $Z(N = 55) = -.2330$, $p = .8157$. The Kruskal-Wallis to compare ROCFT organizational age-corrected z-scores across the three samples was also nonsignificant, $X^2(N = 85) = 5.3350$, $p = .0694$.

A final post hoc analysis of differences among samples attempted to reduce the variance accounted for by IQ by performing analyses according to level of IQ. Each condition was subdivided according to its median (median values were included in the subset with higher IQs). The median IQs were 98 for the NI sample, 102 for the LD sample, and 112 for the NC sample. With the variance in IQ thus reduced, separate comparisons for the lower level of IQ and for the upper level of IQ revealed that IQ was not significantly different among the three samples: for the lower level of IQ, $F(2,45) = .9964$, $p = .3772$; for the upper level of IQ, $F(2,49) = 2.7871$, $p = .0714$. Furthermore, using levels of IQ, IQ no longer accounted for a significant

proportion of variance for the HVOT total score in the multiple regression equation.

Regardless of IQ level, the differences between the NI and NC samples on HVOT total score was nonsignificant, $F(1,18) = 1.933$, $p = .181$, for the lower level of IQ, and $F(1,31) = .082$, $p = .777$, at the upper level of IQ (Table 15).

For the ROCFT total score, IQ did account for a significant proportion of the variance in the multiple regression equation for the lower level of IQ only, $F = 5.788$, $p = .0225$ (as noted earlier, Bonferonni adjustments were not used in the multiple regression equations in order to avoid Type II errors). At the upper level of IQ, with age as the covariate, the samples were not significantly different, $F(2,40) = 1.950$, $p = .156$ (Table 15). However, at the lower level of IQ, controlling for age, the main effect for condition for the ROCFT total score was $F(2,37) = 10.322$, $p < .001$ (Table 15).

To further explore this significant difference among samples on the ROCFT total score at the lower levels of IQ, pairwise samples were compared using analyses of covariance with age as the covariate. The LD and NC samples were not significantly different, $F(1,20) = .593$, $p = .450$. However, the NI sample obtained significantly lower scores than both the NC and LD samples, $F(1,25) = 15.229$, $p = .001$, for the comparison with the NC sample, and $F(1,28) = 13.043$, $p = .001$, for the comparison with the LD sample.

Table 15

HVOT and ROCFT Scores by Condition by IQ Level

	Condition								
	NI			LD			NC		
Test	M	SD	N	M	SD	N	M	SD	N
HVOT total									
Lower IQ	21.1	3.9	13		N/A		22.9	2.1	9
Upper IQ	22.9	3.1	19		N/A		23.9	3.1	14
HVOT IR									
Lower IQ	.615	.77	13		N/A		1.00	.76	9
Upper IQ	.895	1.1	19		N/A		.47	.74	14
ROCFT total									
Lower IQ	14.6	7.4	18	24.3	8.2	13	23.2	9.5	10
Upper IQ	24.6	6.6	13	22.6	8.7	16	25.2	9.1	15
ROCFT OS									
Lower IQ	1.3	.6	18	2.0	1.3	13	1.8	1.2	10
Upper IQ	1.8	.9	13	2.4	1.5	16	2.1	1.3	15

Note. IR = Isolate Response; OS = Organizational Score.

Comparison of samples through Mann-Whitney and Kruskal-Wallis analyses for the HVOT isolate response score and the ROCFT organizational score revealed no significant

differences according to samples. At lower levels of IQ, the Mann-Whitney for comparison of the NI and NC samples on the HVOT isolate response score resulted in $Z(N = 22) = -1.1707$, $p = .2417$. At higher levels of IQ, $Z(N = 33) = -1.2334$, $p = .2174$ for the comparison of the NI and NC samples. For the ROCFT organizational score (analyzed with Kruskal-Wallis tests), the differences among samples were nonsignificant, $X^2(N = 41) = 3.6984$, $p = .1574$, at lower levels of IQ, and $X^2(N = 44) = 1.3345$, $p = .5132$ at upper levels of IQ.

Summary of Results

The inter-rater reliabilities according to two-tailed Pearson correlations were excellent for Mings' (1987) scoring for the ROCFT total score, and adequate for Waber & Holmes' (1985) scoring of ROCFT organizational score and for Beery's (1989) VMI. However, percentage of agreement data revealed that approximately one-third of protocols for each test displayed percentages of agreement below 90%.

A second set of data revealed statistically significant differences among the 3 samples in sex ratio, socioeconomic status, and IQ. In particular, the NI sample had the lowest mean socioeconomic status and the lowest mean IQ. The LD sample had the highest proportion of males/females, and fell in the middle on socioeconomic status and IQ. The NI sample had the highest proportion of females/males, the highest socioeconomic status, and the highest IQ. Thus, the fact

that the samples were not demographically comparable restricts the conclusions that can be drawn about other results.

Within the NI and LD samples, the tests were not administered randomly. The youngest children in the NI sample were more likely than older children to receive only the HVOT than to receive both the HVOT and the ROCFT or only the ROCFT. Children in the NI sample who received only the ROCFT displayed significantly lower IQs than children who received only the HVOT. Similarly, within the LD sample, children who received ROCFTs tended to have lower IQs than children who did not receive ROCFTs. Therefore, the HVOT NI sample is somewhat younger than the general NI sample, and ROCFT results will be affected by the fact that NI and LD children who received the ROCFT are more impaired than children who did not receive the ROCFT.

In terms of the criterion of demonstrating developmental changes, the HVOT total score and the ROCFT total score and organizational score were successful, displaying significant increases with age (especially for comparisons between 6-7 years and older children). The HVOT isolate response score did not display significant developmental changes.

Construct validity data revealed the following significant correlations: HVOT total score with IQ (for the NI sample) and VMI (for the NC sample only, with IQ controlled); HVOT isolate response score with BD (for the NI

sample) and the VMI (for the NC sample, with IQ controlled); ROCFT total score with PC and OA (for the NI sample), VMI (for the NI, LD, and combined samples, as well as the NC sample when IQ was controlled), and IQ (for the NI sample); and ROCFT organizational score with OA and PC (for the LD sample) and VMI (for the LD, NC, and combined samples when IQ was controlled).

Finally, in terms of differences between the samples on HVOT or ROCFT scores, no differences were noted when controlling for IQ. However, when IQ was not controlled, the NI sample performed significantly worse than the LD and NC samples on the ROCFT total score. No differences between samples were noted on the HVOT total score, HVOT isolate response score, or ROCFT organizational score.

CHAPTER 5
DISCUSSION

The results of this research demonstrated the benefits as well as the limitations of the HVOT and the ROCFT in neuropsychological assessment of children. Three sets of findings were explored. One set of analyses related to the utility of two scoring systems for the ROCFT, particularly the inter-rater reliabilities. This set of analyses also explored the inter-rater reliability for the VMI. Next, information about how the HVOT and the ROCFT relate to age and sex was evaluated. Correlational data also provided information about the construct validity of the HVOT and the ROCFT. Finally, a set of analyses explored the differences in performance on the HVOT and the ROCFT among samples of neurologically impaired, learning disabled, and normal children aged 6 through 11.

Evidence Related to Scoring Systems

Mings' (1987) Scoring System for the ROCFT Total Score

Mings' (1987) scoring system for the ROCFT demonstrated excellent inter-rater reliability of .9791, despite the fact that neither rater received any training in the scoring system. Furthermore, the two raters did not consult at all about their interpretations of various items in the scoring system. As with the traditionally used scoring systems for

the ROCFT total score, children's scores increased significantly with age. Therefore, Mings' (1987) scoring system captures the developmental trends other researchers have reported for the ROCFT.

Reliability and validity data which will be further explored in later sections of this discussion support the criterion and construct validity of Mings' (1987) scoring system for the ROCFT total score.

Despite these promising preliminary results, multiple problems exist with Mings' (1987) scoring system for the ROCFT total score. One-third of the 33 protocols scored by two raters displayed percentages of agreement below 90%. Although this is still acceptable, especially given the number of items (144) and the high inter-rater reliability for the total score, the low percentage of agreement indicates that Mings' (1987) scoring system requires further operationalization of items in order to increase agreement levels for individual items. An analysis of which items tend to result in disagreement, followed by appropriate revisions, would be a helpful first step in such an effort.

Furthermore, Mings' scoring system has not been normed, and its comparability to the traditional norms for the ROCFT are questionable. Although Mings' (1987) scoring system follows the traditional outline of 18 criteria to be judged at up to two points each, his scoring system offers much more variability within those points per item. With traditional scoring, any misplacement or inaccuracy results

in a loss of at least one point; in contrast, Mings' (1987) scoring system may result in a loss of only 1/4 point or a 1/2 point. On the other hand, minimally misplaced or inaccurate items under traditional, vaguer scoring systems might result in full credit because of a rater's reluctance to deduct a full point. Mings' (1987) system, in contrast, allows the rater to reduce the score only slightly. Thus, Mings' (1987) system allows for "extra credit" compared to traditional scoring systems for some items, but on other items may result in greater point loss.

Indeed, in comparison to Karapetsas and Kantas (1991) norms for the ROCFT, it seems that Mings' (1987) system may result in lower scores for younger children and higher scores for older children in the NC sample. In particular, Karapetsas and Kantas' (1991) norms are 5.3 points higher for 6 1/2 to 7 1/2 year olds than the current sample's norms for 6 through 7 year olds (respectively, mean of 21.7, s.d. of 7.3, versus mean of 16.4, s.d. of 7.4). In contrast, 8 1/2 to 9 1/2 year olds in Karapetsas and Kantas' (1991) sample obtained means that were 7.9 points lower than the 8 through 9 year old sample in this normal control sample (respectively, mean of 23.0, s.d. of 6.6, versus mean of 30.9, s.d. of 4.3). Similarly, Karapetsas and Kantas' (1991) 10 1/2 to 11 1/2 year olds received mean scores 5.6 points lower than the normal control subjects in this project (respectively, mean of 25.8, s.d. of 6.9, versus mean of 31.4, s.d. of 2.8). Given that the normal control

sample in this project was small and of higher IQ and higher socioeconomic status than average, the normative data from this research are far from ideal, and the difference between these and Karapetsas and Kantas' (1991) norms may reflect primarily problems with this sample. However, further data are necessary before confidently answering the questions about norms for Mings' (1987) scoring system.

A ceiling effect may occur with Mings' scoring system. The standard deviations become increasingly lower with increasing age, and the mean for the normal 10 through 11 year olds is only 1.7 standard deviations from the maximum score of 36. However, ceiling effects are a problem for all scoring systems of the ROCFT. Indeed, no child obtained a perfect score on Mings' (1987) scoring system for the ROCFT, raising the possibility that Mings' scoring system may be an improvement over other scoring systems in this respect.

Because this project did not directly compare Mings' (1987) scoring system with other scoring systems for the ROCFT. Therefore, it is impossible to move beyond speculation regarding the relative advantages and disadvantages of Mings' (1987) scoring system for the ROCFT total score.

Thus, the data from this project provide promising evidence for the potential use of Mings' (1987) scoring system for the ROCFT, with several caveats. In its favor, Mings' scoring system has excellent inter-rater reliability for the total score and seems to have criterion and

construct validity (as discussed below). However, the percentage of agreement for individual items is sometimes low, and some adjustments are required to increase the percentage of agreement before further use of this scoring system is recommended. In addition, use of previously published norms to interpret Mings' (1987) scoring for the ROCFT is clearly unwise, making this scoring system virtually useless clinically for the time being. In addition to the need for further normative data, the reliability and validity data is only preliminary, and needs to be replicated and expanded upon before Mings' (1987) scoring system can be used with confidence.

Waber and Holmes' (1985) Scoring for the ROCFT Organizational Score

The inter-rater reliability for Waber and Holmes' (1985) scoring system for organizational quality was .8840 in this project, within the acceptable but not ideal range. Furthermore, it is substantially lower than the 95% agreement reported by Waber and Holmes (1985). Indeed, the number of protocols with less than 100% percentage of agreement for total score was 10 out of 33 protocols, or 30.3%, substantially lower than the 95% reported by Waber and Holmes (1985). Significantly, Waber and Holmes (1985), who devised the scoring system, were also the raters in their project. In contrast, both raters in this research were clinical psychology graduate students, neither of whom is particularly expert in ROCFT scoring.

Although the inter-rater reliability was adequate for this research, in order for Waber and Holmes' (1985) scoring system to be of substantial benefit clinically, the average clinician or technician who does not specialize in ROCFTs must be able to accurately score the ROCFT. This project indicates that Waber and Holmes' (1985) scoring system may not meet this standard.

However, in support of Waber and Holmes' (1985) scoring system, some of the current data supports their findings. First of all, scores increased with age to a degree that was statistically significant, supporting Waber and Holmes' hypothesis that the ROCFT organizational score is sensitive to developmental trends. Furthermore, the scores obtained for this NC sample seem to correspond to the norms reported by Waber and Holmes (1985). Waber and Holmes (1985) report norms for a 13-point version of their 5-point scale, making direct comparison difficult; however, they report the corresponding 5-point score for each of their 13 points. Waber and Holmes' (1985) 6 and 7 year olds scored at the upper range of the first level and the lower range of the second level: the mean for the current NC sample was 1.3, s.d. of .6, for the 6-7 year olds. The 8 and 9 year olds in Waber and Holmes' (1985) sample obtained scores at the upper end of the second and lower end of the third level, respectively: the 8-9 year olds in this NC sample obtained a mean score of 3.1, s.d. of 1.4. Finally, their 10 and 11 year olds scored at the middle and upper range of the third

level, respectively: the mean score for this age range in this study was 3.1, s.d. of 1.4. However, confirmation of results by this NC sample is questionable, since this NC sample is small and unrepresentative of the population in terms of race, sex, socioeconomic status, and IQ.

If the inter-rater reliability difficulty were resolved and future data supports the usefulness of the use of the ROCFT organizational score, Waber and Holmes' (1985) organizational scoring system holds some promise. However, as with Mings' (1987) scoring system for the total score, more evidence must be presented in favor of Waber and Holmes' (1985) scoring system, especially in terms of increasing inter-rater percentage of agreement for clinicians who do not specialize in the ROCFT.

Inter-Rater Reliability for Beery's (1989) VMI

The inter-rater reliability for the VMI was .8684, which is in the acceptable but not ideal range. It is less than the mean inter-rater reliability of .93 described by Beery (1989), but within the range of .58 to .99 that he reported. Of especial concern is the 24.2% of cases in this sample for which the percentage of agreement for individual items was below 90%. All of these cases were resolved by a third rater. In the most striking cases requiring a third rater, large differences (e.g., 15 points) resulted from disagreement on a single item in a situation when that single disagreement determined whether discontinuance

criteria was met. When one rater discontinued, but the other rater went on to score the rest of the VMI, large discrepancies sometimes resulted.

Although it is not impossible that such discrepancies resulted from sporadic carelessness on the part of one or both raters, it is likely that the raters' scoring reflected the same judgements that are made regularly in clinical situations. The occasional large discrepancy in scores which occurred in this project is of especial concern clinically, when diagnostic decisions may be partially decided by the VMI. In those instances when the VMI stands out as a substantially lower score than a child's scores on other items, it seems wise for a second clinician to examine the VMI score to confirm its accuracy. In addition, these results indicate that, in contrast to Beery's (1989) claims and in accordance with Spreen and Strauss (1991), some training is necessary for reliable scoring of the ROCFT.

Relationship of the HVOT and the ROCFT to Age

Hypothesis 1a) The HVOT total score, the HVOT isolate response score, the ROCFT total score, and the ROCFT organizational score, would display significant improvements with increasing age.

Children's scores on the HVOT total score, the ROCFT total score, and ROCFT organizational score improved significantly with age. Furthermore, multiple regression analyses revealed that age accounted for more variance than

any other factor for the HVOT total score and the ROCFT total score. Any age effects for the HVOT isolate response score, however, did not reach statistical significance, despite the fact that 58% of the worst isolate response scores (scores of 2 or 3) occurred in the youngest age range.

The results for the HVOT total score and the ROCFT total and organizational scores were consistent with prior research demonstrating that children's scores on the HVOT and on the ROCFT increase substantially as children grow older. The current findings support such evidence that indicates these measures are sensitive to developmental changes (Karapetsas & Kantas, 1991; Karapetsas & Vlachos, 1992; Kirk, 1992; Seidel, 1994; Waber and Holmes, 1985).

HVOT Total Score

In particular, the current results replicate Kirk's (1992) and Seidel's (1994) results for the HVOT total score. Both Kirk (1992) and Seidel (1994) found that the youngest children displayed significantly lower performances than the oldest children (5-6 versus 11-13 year olds in Kirk's (1992) study, and 5-7 versus 10-11 year olds in Seidel's (1994) project). These results, that 6-7 year olds score significantly worse than 8-9 year olds and 10-11 year olds, but that 8-9 and 10-11 years are not significantly different, generally duplicate Kirk's (1992) and Seidel's (1994) research. In addition, the scores of this normal

sample approximate the norms of Kirk (1992) and Seidel (1994). However, the current results suggest that a significant shift in HVOT scores occurs between 6-7 and 8-9 year olds.

Thus, the HVOT clearly is sensitive to developmental changes over the course of the 6-11 year period; however, its sensitivity to changes from year to year has not been established. The fact that mean scores are in the low to mid-20s for children aged 6-11 indicates that the possible range of scores is rather small for detection of year to year changes. However, the ceiling effect for the HVOT total score is certainly not as great with children as with adults.

HVOT Isolate Response Score

No statistical evidence demonstrated that the HVOT isolate response score was sensitive to developmental changes.

ROCFT Total Score

As with the HVOT total score, the previously published data regarding developmental changes was replicated. In particular, Karapetsas and Kantas (1991) and Karapetsas and Vlachos (1992) determined that 5 1/2 to 6 1/2 year old children obtained significantly worse ROCFT total scores than all groups over 7 1/2 years of age. In this sample, 6-7 year olds received significantly lower scores than 8-9 and

10-11 year olds. All three of these studies are consistent with the proposed developmental shift in ROCFT performance at around age 8. The similarity in these results is especially compelling given the scoring differences (Mings' (1987) scoring in this study versus traditional scoring) and the cultural differences (Gainesville, Florida, and Hartford, Connecticut, versus Crete and Greece). Thus, the ROCFT total score is sensitive to developmental changes in the 6-11 age range. However, as discussed above, the possibility of ceiling effects with Mings' (1987) scoring system should be explored.

ROCFT Organizational Score

As reported by Waber and Holmes (1985), organizational scores tended to increase with age. Children aged 6-7 years obtained significantly lower scores than 8-9 and 10-11 year olds, while 8-9 year olds and 10-11 year olds did not significantly differ. However, in the current small sample, the scores for the 8-9 year old NC sample were greater than the scores for 10-11 year olds. This counterintuitive result seems likely to be the result of small NC sample size ($N = 5$ in the 8-9 year old age range, and $N = 8$ in the 10-11 year old age range).

Because Waber and Bernstein (1994) reported that LD children generally failed to display improvement in scores beyond 6-8 years of age, the current LD sample's results according to age were of particular interest. The results

of this study are in contrast with Waber and Bernstein's (1994) conclusions. Indeed, the LD sample was the only sample in which 10-11 year old children obtained significantly higher scores than 8-9 year old children. These inconsistent findings may be the result of the low sample size in the current project; however, further exploration of LD children's performance on the ROCFT organizational score is needed.

Implications of these Developmental Changes

These results indicate that children's visuospatial and visuomotor skills are changing substantially during the period from 6 through 11 years of age. In particular, the HVOT results indicate that between the ages of 6-7 years and 8-9 years, a significant shift occurs in children's abilities to mentally manipulate objects in space. Interestingly, this shift occurs at approximately the same time as the shift from the preoperational stage to formal operations (Piaget, 1936/1977; Piaget, 1937/1977; Piaget & Inhelder, 1969). In addition, within Ellis and Young's conceptualization of object perception, the ability to mentally manipulate pieces of objects in space to form a meaningful whole would logically correspond to the ability to mentally manipulate viewer-centered objects in space to form object-centered objects. Thus, it is likely that children's abilities to shift from object-centered to

viewer-centered views of objects may also display significant changes during this period.

Because the ROCFT relates to so many abilities (visuoperceptual, visuospatial, executive, and graphomotor functions), the meaning of children's improvement with age is more difficult to isolate. However, the shift between ages 6-7 and ages 8-9 was again apparent, and consistent with Piaget's (1936/1977; 1937/1977; Piaget & Inhelder, 1969) theory of a developmental shift between the preoperational stage and formal operations. Rather than reflecting a specific change, the improved ROCFT performance with age probably reflects a number of changes in visuoperceptual/visuospatial skills, executive functioning (planning and organizing the figure), and graphomotor ability.

Relationship of the HVOT and the ROCFT to Sex

No effects of sex were discerned in this study for any of the four dependent variables. Thus, the data on the HVOT total score is consistent with Seidel's (1994) findings, rather than Kirk's (1992) results. It is possible that the smaller samples of Seidel (1994) and the current project resulted in insufficient power to discern sex effects. Alternatively, the possibility of some selection bias in Kirk's (1992) study cannot be ruled out.

However, for the ROCFT, most data suggest that sex does affect total score, with female children obtaining higher

scores than male children, but not organizational score (Karapetsas & Kantas, 1991; Karapetsas & Vlachos, 1992; Waber & Holmes, 1985). Thus, the current data demonstrating an absence of sex differences are in contrast to the published data for the ROCFT total score. Unfortunately, the only large samples for the ROCFT have been with Greek children. Therefore, it is impossible at this point to determine whether the different results reflect cultural differences or the fact that the current sample size was too small to discern differences in ROCFT performance according to sex. Indeed, the fact that male children's scores on the ROCFT total score were 2.3 points higher than female children's in this sample, despite failure to attain statistical significance, suggests that small sample size may be the culprit behind this project's failure to replicate the sex effects reported for the ROCFT total score. As a further complication, this sample was somewhat weighted towards finding that females outperform males because the normal sample had an overrepresentation of female children while the NI and LD samples contained a majority of males. If the presumption that NI and LD children are more likely to experience difficulties is accurate, the female children for the whole sample would be expected to display better scores than males. Thus, the current failure to replicate the sex differences found in other studies may relate to specific problems with the

current sample or to cultural differences between the United States versus Greece and Crete.

Based on the lack of consistency for data for the HVOT total score and the ROCFT total score, as well as on the relative paucity of research and the small sample size for the current research, it is too early to come to any conclusions about sex effects on the ROCFT and the HVOT. Nevertheless, the groundwork is being laid for continuing research into these measures, and the conclusions should grow clear as further data are published.

Construct Validity for the HVOT and the ROCFT

Hypothesis 2): Correlational data would establish evidence of construct validity for the HVOT and the ROCFT.

HVOT Total Score

Hypothesis 2a): The HVOT total score would correlate significantly with IQ, Picture Completion, and Object Assembly, but not with the VMI.

When the HVOT was correlated with other measures of ability (Vocabulary Scaled Score, Block Design Scaled Score, IQ, Picture Completion Scaled Score, Object Assembly Scaled Score, and the VMI), the most consistent finding was a significant positive correlation ($r = .52$ for the NI sample and $r = .43$ for the combined sample) between the HVOT total score and Object Assembly. However, using partial correlations to control for IQ revealed that the Pearson

correlations were significantly affected for IQ: when partial correlations controlling for IQ were employed, Object Assembly did not display a substantial correlation with the HVOT total score. A sizeable correlation ($r = .42$) with IQ for the NI sample only was also evident. When IQ was controlled, the HVOT total score was significantly correlated with the VMI (partial correlation = .46). Thus, the following predictions for the HVOT total score were upheld: positive correlation with Object Assembly (but only for the NI and combined samples when IQ is not controlled) and positive correlation with IQ (but only for the NI sample). The prediction for a positive correlation with Picture Completion was not upheld. In addition, the HVOT total score was correlated with IQ when.

Thus, the association between the HVOT (requiring mental spatial manipulation of pieces of an object) and Object Assembly (requiring physical manipulation of pieces of an object) received initial support; however, further analyses using partial correlations to control for IQ revealed that the high correlation between Object Assembly and the HVOT total score was largely related to IQ, which accounted for a significant proportion of the variance for the HVOT total score in a multiple regression model. The HVOT's failure to display significant correlations with Picture Completion suggests that the HVOT requires less attention to detail than Picture Completion, and may be weighted towards spatial somewhat more than perceptual skills.

The low correlation of Object Assembly and IQ with the HVOT for the NC sample was unexpected, and indicates that no conclusions based on these data can be drawn regarding the HVOT's construct validity. In particular, the inconsistent IQ data is in contrast to data with adults, which demonstrates a regular association with the HVOT total score. The inconsistent results for Object Assembly and IQ is potentially attributable to random error, to the smaller sample size for the NC sample compared to the NI and combined sample, and to the more restricted range of scores in the NC sample. Alternatively, the correlations may be significant for the NI sample but not the NC sample because impairment affects both measures, while normal scores are more randomly distributed.

These correlational data for the HVOT are somewhat consistent with Hilgert and Treloar's (1985) and Seidel's (1994) results. Major differences between these findings and Seidel's (1994) results include (1) the magnitude of his correlations are much larger, (2) Block Design displayed a higher correlation than Object Assembly ($r = .625$ versus $r = .488$, respectively), and (3) the correlation between Picture Completion and the HVOT approached the magnitude of the correlation between Object Assembly and the HVOT ($r = .459$ for Picture Completion, $r = .488$ for Object Assembly). However, his general findings that the HVOT correlated more with Performance IQ subtests than with Verbal IQ subtests received limited support, indicating that the HVOT may have

construct validity as a visuospatial task, with the caveat that inconsistency between the NI and NC samples preclude any conclusions regarding construct validity for the HVOT total score.

HVOT Isolate Response Score

Hypothesis 2b): The number of HVOT isolate responses would correlate negatively with IQ.

The only significant correlation between the HVOT isolate response score and an independent variable was with Block Design for the NI ($r = -.69$). The negative correlation is expected, because a high number of isolate responses is indicative of dysfunction, while a low score on Block Design is suggestive of impairment. Thus, the predicted correlation with IQ was not observed, although Block Design is the subtest most highly correlated with Performance IQ. The correlation between Block Design and the HVOT isolate response score for only the NI sample seems to reflect the fact that all the children with scores of 3, and most of the children with scores of 2, were in the NI group, for whom Block Design, given the lower IQs in the NI sample, should also be impaired. However, because the correlation with IQ itself is not elevated, the correlation with Block Design reflects more than general intellectual ability. One likely hypothesis is that the HVOT isolate response score is sensitive to executive dysfunction (e.g., difficulties with abstraction, problem solving, impulse

control). Among the Performance subtests, Block Design is frequently noted as the subtest that is most abstract, a traditionally executive function. Alternatively, the HVOT isolate response score may be correlated with Performance IQ (Block Design provides the best estimate of Performance IQ among subtests employed).

This solitary positive result, which was not confirmed for the NC or combined samples, suggests that the HVOT isolate response score's utility is quite limited, especially as a research measure when the incidence of more than 1 isolate response appears quite rare. Although the clinician should clearly take note of a child who gives a number of isolate responses, the HVOT isolate response score does not seem to be of substantial clinical utility in most cases.

The ROCFT Total Score

Hypothesis 2c): The ROCFT total score would correlate significantly with IQ, Picture Completion, Object Assembly, and the VMI.

The most significant correlational finding for the ROCFT total score was its high positive correlation with the VMI (although this correlation was contingent upon controlling for IQ via partial correlations for the NC sample), with Pearson $r = .59$ for the NI group, $r = .55$ for the LD group, and $r = .46$ for the combined sample, and partial $r = .66$ for the NC sample. Other results indicated

a significant correlation with Object Assembly for the NI and LD samples only ($r = .51$ for the NI sample; $r = .53$ for the LD sample), and with IQ for the NI sample only ($r = .48$). However, in post hoc analyses, partial correlations controlling for IQ substantially reduced the correlation between the ROCFT total score and Object Assembly for the LD sample only.

The correlation between the ROCFT total score and the VMI was predicted, as both are related to perceptual accuracy and graphomotor ability. The less consistent correlation with Object Assembly, also predicted, relates to IQ, but also may indicate an association between the ROCFT total score and visuospatial and constructional skill. The lack of a significant correlation with Picture Completion indicates that the ROCFT may be more involved with spatial and constructive skills than attention to detail. Finally, the correlation with IQ for the NI sample is consistent with the hypothesis that the ROCFT, like IQ scores, may be sensitive to general impairment.

The problematic feature of the ROCFT total score correlational data, as with the HVOT total score data, is the lack of consistency of correlations between samples, especially the failure to obtain substantial correlations in the NC sample (except for a high correlation between the ROCFT total score and the VMI when controlling for IQ via partial correlations). As with the HVOT total score, the hypothesis that NI and, to a lesser extent, LD, children

score low on multiple measures, thereby increasing correlation, while a normal population may show more variability around a mean score, thereby decreasing correlation, is logical. It is also possible that the lower sample size for the NC sample versus the LD and the NI samples contributes to (but does not account entirely for) the lack of significant correlations.

The ROCFT Organizational Score

Hypothesis 2d): The ROCFT organizational score would correlate significantly with IQ.

The ROCFT organizational score's most consistent correlation was with Object Assembly for the NI and LD samples only ($r = .40$ for the NI sample and $r = .57$ for the LD sample); however, partial correlations controlling for IQ revealed that the correlation with Object Assembly for the NI sample was largely attributable to IQ. Picture Completion correlated significantly with the ROCFT organizational score for the LD sample only ($r = .52$). The prediction for IQ was not clearly upheld, indicating that the ROCFT organizational score is not highly related to overall level of cognitive functioning. Controlling for IQ through partial correlations, the ROCFT organizational score was highly correlated with the VMI for the LD, NC, and combined samples (partial $r = .60$ for the LD sample; partial $r = .51$ for the NC sample, and partial $r = .45$ for the combined sample).

The correlation with Picture Completion for the LD sample was not predicted, and suggests possible deficits in detail-oriented perception in the LD sample. The ROCFT organizational score's high partial correlation (controlling for IQ) with the VMI for the LD and NC samples indicates that, like the total score, the organizational score is related to general graphomotor abilities.

The generally consistent finding of nonsignificant correlations for the NC sample was apparent for the ROCFT organizational score as well as for the previously discussed HVOT and ROCFT scores, and is potentially attributable to the same hypotheses previously raised. It is noteworthy that examination of pediatric renal patients results in similar differences in correlational patterns, with renal patients displaying significant correlations while normal controls do not (Fennell, Fennell, Carter, Mings, Klausner, & Hurst, 1990). However, with such low correlations within the NC sample, it is impossible to draw firm conclusions regarding the construct validity of the HVOT and the ROCFT.

Differences Among Samples on the HVOT and the ROCFT

Hypothesis (3) After controlling for any effects of age, IQ, and sex, the children with neurological impairment or with learning disabilities would display significantly more impaired performance than normal children on the following measures: (1) HVOT total score, (2) the number of

HVOT isolate response errors, (3) the ROCFT total score, and (4) the ROCFT organizational score.

HVOT Total Score

Because the LD sample with HVOT results was so small, only the NI and the NC samples were compared on the HVOT total score. When age and IQ were employed as covariates, no significant results were obtained on analyses of covariance. Thus, HVOT scores for groups of children do not differ between fairly normal and NI children after controlling for differences in IQ between the NI and NC samples. Furthermore, when age was the only covariate or when scaled scores were used to control for age, the NI and NC samples were not significantly different, nor did the difference approach significance.

The current results are in contrast to Seidel's (1994) findings, whose sample sizes were somewhat larger (49 children in both his samples versus 32 NI and 23 NC for this sample). Seidel's (1994) NI and NC samples were significantly different, despite the fact that he controlled for IQ by matching NI and NC samples by IQ. The current sample's IQ scores were about 22 points higher than Seidel's (1994) NC sample and about 16 points higher than this project's NI sample. Given the data about relationship between HVOT total scores and IQ in both this project and Seidel's (1994) research, the difference between NI and NC samples in the current study should be greater than Seidel's

(1994) findings, not less. It is possible that using a covariate for IQ rather than matching subjects by Verbal IQ resulted in the nonsignificant results for the analysis of covariance using IQ as a covariate; however, this would not affect the analysis when IQ was not a covariate.

Seidel (1994) does not identify possible selection bias to determine which children in his NI sample received HVOTs. It is possible that children in his clinical sample were only given HVOTs if there was substantial suspicion of visuospatial impairment. If so, this selection bias would significantly affect his results so that the difference between groups appeared greater than would have occurred in a general sample of NI children. Although differences in sample size may account for the differences between these results and Seidel's (1994) findings, the degree of difference between results indicates that whether NI and NC children display different performances on the HVOT total score is currently an open question.

HVOT Isolate Response Score

The HVOT isolate response score consistently failed to display any differences in performance between NI and NC children. Although the 2 children who gave 3 isolate response errors were in the NI sample, such results were too rare to attain statistical significance. When combined with the minimal results of the correlational analyses, the HVOT isolate response score appears to be extremely limited

clinically. It may be informative when substantially elevated, but in virtually all cases the HVOT isolate response score is likely to be within the normal range.

The ROCFT Total Score

As with the HVOT total score, results of analysis of covariance were nonsignificant when IQ was included as a covariate in addition to age in the analysis of covariance. However, when IQ is no longer controlled out through analysis of covariance, the differences among samples on the ROCFT total score were significant. In particular, the NI sample obtained significantly lower scores than the NC sample; the differences between other pairs of groups approached significance. Analyses of results by upper and lower levels of IQ indicated that the differences between the NI and NC samples reflected differences between subjects at the lower levels of IQ. In fact, selection criteria predispose the groups to be different at lower levels of IQ, because the cutoff for the NI sample is lower than the cutoff for the NI sample. Thus, a difference in ROCFT total score between NI and NC samples does exist; however, differences in global functioning (as measured by IQ) account for most of the difference.

ROCFT Organizational Score

The three samples did not display significant differences in ROCFT organizational scores. In contrast,

Waber and Bernstein (1994) found that the ROCFT organizational scores were significantly lower for LD than for NC children. The fact that the current results were in the predicted direction and bordered upon significance suggests that greater power (either through increased sample size or use of the unpublished 13 point version that reduces the problems of non-normality, allowing for parametric statistical analysis) might have resulted in significant results.

Implications of Differences Among Samples

Often the first step in determining the usefulness of a neuropsychological assessment instrument for a neurologically impaired population is to determine whether it is sensitive to neurological impairment, termed "neurological validity"(Taylor & Schatschneider, 1992, p. 259). These results support the neurological validity of the ROCFT total score.

Because the ROCFT calls upon so many different abilities, its greater sensitivity to neurological impairment was not surprising. The HVOT, despite having been touted for so many years as a screening measure, calls upon a relatively restricted range of functions compared to the ROCFT. Thus, the HVOT might be sensitive to visuospatial or naming difficulties, but not to executive functions or motor ability. The fact that the organizational score for the ROCFT, which would be expected

to be associated with executive functions, was not significantly different among groups supports the possibility that the ROCFT was sensitive to numerous impairments in the NI sample, rather than to a discrete dysfunction.

The diagnostic categories of this NI sample also suggest that detection of specific deficits is unlikely in this NI sample. The majority of the NI sample consisted of children with brain tumors, seizure disorders, and hydrocephalus, disorders in which specific abilities (e.g., visuospatial skills) are unlikely to be selectively disturbed. Thus, tests of specific abilities would not necessarily be expected to display impairment in this NI sample. Furthermore, this NI sample was noteworthy for the chronicity of their neurological disease, with a mean time since diagnosis of approximately four years. Patients in the acute stages of disease are often more likely to display focal difficulties than patients who have progressed beyond the acute stages. Thus, the lack of specific deficits evident may relate to the chronicity of disease for this NI sample as well as to the heterogeneity of the sample.

The failure to find significant differences between the LD sample and the NC sample probably reflects the heterogeneity of the LD sample. The underlying deficits in LD are quite variable, and therefore a heterogeneous sample is unlikely to display consistent areas of impairment. The current results indicate that the ROCFT is not sensitive to

many of the difficulties represented in this LD sample. Indeed, the weighting of the current sample towards reading and other language impairments particularly reduces the likelihood that largely visuospatial and visuomotor tasks like the HVOT and the ROCFT would be able to detect group differences.

Limitations of the Present Study

Several substantial limitations reduce the generalizability and the significance of the results reported. Missing data was a significant problem, further reducing sample sizes for many analyses. Furthermore, the missing data was not randomly distributed, leaving open the possibility that missing information has been selectively left out or removed. Thus, generalizability of the data is somewhat questionable.

Differences in demographic characteristics among the three samples was also problematic. Although in some instances such differences reflected population differences (e.g., the larger proportion of male children in the NI and LD samples, the lower IQ in the NI and LD samples), other differences reflect sampling biases or random sampling errors. For example, the larger proportion of female children in the NC sample, the high mean IQ of the NC sample, and the high socioeconomic status of the NC sample all reflect sampling biases and random error. Rectifying the problems with the NC sample would require substantial

recruiting efforts from average and disadvantaged communities.

The confound between socioeconomic status and condition was particularly troubling, because failure of socioeconomic status to meet the assumption of homogeneity of regression prevented statistical control of socioeconomic status. Because socioeconomic status was confounded with condition, the difference between samples on the ROCFT total score cannot be attributed to neurological differences with complete confidence.

The lack of minority children in all three samples reduces the generalizability of results to non-Caucasian children. Unfortunately, such problems of upper-middle class, Caucasian research subjects is all too common and quite difficult to overcome.

The selection bias in terms of which NI and LD children received which combinations of tests is also problematic. Because children with lower IQs tended to receive the ROCFT only, the ROCFT data for both the NI and LD samples may be skewed towards a more impaired sample. The HVOT data for the NI sample is similarly skewed towards a younger sample. Although some other selection biases (e.g., a systematic bias towards giving measures that are expected to demonstrate difficulties) cannot be entirely ruled out, it is worth noting that every NI child aged 6-11 whose file was examined and who met screening criteria (i.e., appropriate medical documentation of neurological disease and

satisfactory IQ scores) received the HVOT or the ROCFT or both. The consistency with which one or both of these measures were used with NI children aged 6-11 argues against the existence of any clinician biases towards administering the HVOT or ROCFT selectively to children in whom visuospatial or visuomotor difficulties are most expected. The relatively low incidence of significant results also argues against such selection bias.

Low sample size and unequal sample size reduced the power of the analyses, thereby decreasing the likelihood of significant results and decreasing the generalizability of the results. In particular, the low sample size, especially for the LD and NC samples, probably contributed to the inconsistent correlational results among the three samples. Similarly, the heterogeneity of the NI and LD samples is likely to have decreased power through increased between-subjects and within-sample variance.

Finally, except for Mings' (1987) scoring system, the inter-rater reliabilities were not particularly high, and therefore the reliability of the data is less than ideal. Increased training of the raters or presence of additional raters may have improved the inter-rater reliabilities; however, increased training may reduce generalizability to the average clinician who does not have specialized training in these assessment instruments.

Directions for Future Research

In terms of inter-rater reliability issues, further research with Mings' (1987) scoring system may result in refinements of his system that would increase the percentage of agreement. In particular, identification of which items have poor inter-rater agreement may lead to changes which will increase the reliability of Mings' (1987) scoring system for the ROCFT total score. It would also be helpful if a revision of Waber and Holmes (1985) provided criteria that were more oriented towards the general clinician or researcher who does not have particular expertise in the ROCFT. In addition, publication of the 13-point scale that is more normally distributed would assist other researchers. For both of these scoring systems for the ROCFT, comparison studies of the several different scoring systems available would facilitate selection of a scoring system. Additional normative data should also be collected after reliability has been established, and additional projects evaluating reliability and validity data are necessary before these scoring systems could be employed clinically. Finally, more information on training methods for Beery's (1989) VMI would be helpful.

The developmental changes for the HVOT and the ROCFT are beginning to be well-documented, but confirmatory data remains helpful. In particular, normative data for the ROCFT for a large sample of children in the United States would provide valuable information about the ROCFT total

score and organizational score. In addition, such a project would assist in resolving the issue of whether the different findings regarding males' versus females' performance on the ROCFT relate to cultural differences between the United States versus Greece and Crete (the sites of the large normative samples).

Questions also remain regarding whether a particular developmental shift occurs around age 8 on the HVOT and the ROCFT, and whether ceiling effects may be problematic for older children. In particular, the HVOT results suggest that a developmental shift may occur in children's ability to form object-centered views of objects; research to evaluate children's ability to recognize unusual views of objects would be useful in exploring this hypothesis.

Furthermore, information regarding developmental changes in LD children are mixed, with Waber and Bernstein (1994) reporting that LD children's ROCFT organizational scores fail to improve after a certain age, while this project indicated that the greatest improvement for the LD sample occurred between the middle and oldest age ranges. Further evaluation of LD children's performance on the ROCFT (both the total score and the organizational score) are therefore indicated.

This sample revealed no differences according to sex in HVOT total score or ROCFT total score, both of which have displayed differences according to sex in other projects. Therefore, continued exploration of the questions about

differential performances according to sex for the HVOT total score and the ROCFT total score are recommended.

In terms of published data, this project is the third attempt to examine construct validity for the HVOT and the first attempt to explore construct validity in the ROCFT. In addition to attempts to replicate or refute these results, further examination of the different correlational patterns observed depending on sample is recommended, along with attempts to identify the cause of the different patterns observed. Employing large samples of normal children will be crucial to further exploration of the question of construct validity. In addition, especially with the ROCFT, inclusion of executive system tasks would shed valuable light on the role of executive functions in children's performances on the ROCFT.

The HVOT total score's failure to display differences between the NI and NC samples is in contrast to Seidel's (1994) results. Therefore, the question of whether HVOT scores are different for NI versus NC children requires further exploration. In addition, this is the first project to examine the ROCFT total score and organizational score in NI children, and further efforts to replicate or refute these results are required. Furthermore, this research has examined neurological validity with a heterogeneous neurologically impaired sample with diffuse, chronic dysfunction. Thus, research with children with discrete localizable lesions would provide valuable data regarding

the HVOT and the ROCFT's utility in evaluating localized lesions, as well as information describing differences in children's performances according to site of lesion.

Summary and Conclusions

Despite the numerous limitations of this project, several hypotheses received support. Limitations included nonrandom missing data for the NI and LD samples, demographic differences between groups for sex, socioeconomic status, and race, unequal and small sample sizes, and some selection biases for the NI and LD samples.

One noteworthy positive result was the evidence for reliability and validity of Mings' (1987) scoring system for the ROCFT total score. Although its greatest strength is high inter-rater reliability, it has the potential to be a substantial boon to those clinicians and researchers seeking a more reliable alternative to traditional ROCFT scoring. Much more empirical evidence must be provided, however, including improvement in percentage of agreement for individual items, before clinical use is practical.

These data provided confirmatory evidence for previously published results demonstrating improved performance with age for children on the HVOT total score, the ROCFT total score, and the ROCFT organizational score. Thus, all evidence currently available suggests that the HVOT total score and the ROCFT total and organizational scores are sensitive to developmental trends in middle

childhood. As a result, these measures may be particularly helpful in evaluating children in this age range, although LD children's developmental changes and the potential for ceiling effects should be examined further.

Although correlational data was mixed, the HVOT total score, ROCFT total score, and the ROCFT organizational score tended to be associated with other visuospatial and constructive tasks, and sometimes with global intellectual ability. In particular, the ROCFT total score displayed the predicted high correlation with the VMI (both are tests of graphomotor skill).

The pattern of correlational data was noteworthy for the inconsistency of the correlations across samples. In particular, the NC sample rarely displayed significant correlations. While this result is probably partially the result of a low sample size for the NC sample, it is likely that impaired scores are associated with other impaired scores, while normal scores may display a more variable and ambiguous pattern. Future research with larger sample sizes will hopefully clarify the potentially complicated relationships between condition (NI, LD, or NC) and the correlations among the selected variables.

After controlling for general cognitive abilities (as represented by IQ), neither the HVOT nor the ROCFT total scores displayed a significant difference between samples. However, without controlling for IQ, the samples were significantly different on the ROCFT total score. No

differences among samples emerged for the HVOT total score, HVOT isolate response score, or the ROCFT organizational score. Therefore, the ROCFT total score is the most sensitive of these tests to neurological impairment. Despite the fact that the difference in mean ROCFT scores between the NI and the NC samples are attributable to differences in general cognitive ability (as measured by IQ), the ROCFT total score does meet the criterion of neurological validity insofar as the NI sample obtained significantly worse scores than the NC sample.

These results in certain instances were inconsistent with previous results. Although in some instances the differences are easily attributable to smaller sample size (e.g., the lack of significant results when comparing the 3 samples' ROCFT organizational scores), other results frankly contradict other data. For example, the HVOT data on sex effects in this study is not consistent with Kirk's (1992) finding that males outperformed females on the HVOT. In this respect, these results agree with Seidel (1994), but the failure to find significant effects for condition was a marked contrast to Seidel's results. Indeed, given IQ differences between the NC and NI samples and the significant relationship between IQ and HVOT scores, the current results would be expected to be far more powerful rather than less powerful than Seidel's (1994) results. Further experimental evidence will be necessary to resolve this issue.

Although the ROCFT organizational score was not as able to discriminate between groups as expected, this could easily be attributable to the low range of possible scores and to the low sample sizes.

Failure to display significant differences between samples of NI, LD, and NC samples should not be interpreted as evidence that the HVOT total score and ROCFT organizational score have no clinical use. Because of the heterogeneity of these NI and LD samples, any measure that is primarily sensitive to focal lesions would display such nonsignificant differences among samples.

In summary, the HVOT total score displays developmental changes during the age period 6-11 years. Correlational analyses suggest that it may be associated with visuospatial and visuoconstructive skills. However, the NI and NC samples' HVOT total scores were not significantly different.

In contrast to some early information on the HVOT isolate response score, this project indicated that the HVOT isolate response score is of minimal clinical utility. Although individual children may have isolate responses that are frequent enough to warrant attention, in general the isolate response score contributes a minuscule, if any, addition to neuropsychological testing.

The ROCFT total score emerged as sensitive to developmental changes and to differences between NI and NC children. It was associated consistently with graphomotor ability, and less consistently with visuospatial and

constructive skills. LD and NC children did not score significantly differently on the ROCFT total score, and therefore the sensitivity of the ROCFT total score does not seem to extend to heterogeneous samples of LD children.

Finally, despite difficulties with the scoring system for the ROCFT organizational score, the ROCFT organizational score displayed improved scores with age, indicating that it is able to detect developmental changes for 6-11 year old children. It tended to be associated with graphomotor, visuospatial and visuoconstructive skills. Although the ROCFT organizational scores were not significantly different for the different samples, the difference between the NI and NC samples were in the predicted direction.

In general, the results indicate that, except for the HVOT isolate response score, the HVOT and the ROCFT have the potential to be of substantial assistance in neuropsychological evaluations of children. In particular, changes with age demonstrate that the HVOT total score and the ROCFT total and organizational scores display developmental changes and are therefore likely to be of particular importance in evaluating children. In addition, correlational analyses provide promising preliminary evidence of construct validity (i.e., the measures tend to correlate, albeit inconsistently, with other measures of visuospatial, constructive, or organizational skill). Finally, the observed significant differences between NI, LD, and NC samples support criterion validity for the ROCFT

total score. Thus, the ROCFT total score emerged as the most useful of the four measures evaluated, with some promising results for the HVOT total score and ROCFT organizational score, and with little data to support use of the HVOT isolate response score for other than qualitative purposes.

APPENDIX

TELEPHONE SCREENING FORM

TELEPHONE SCREENING FORM

Name _____

Address _____

_____

Phone Numbers: _____

Thank you for your interest in this project. I'd like to ask you a few questions to make sure your child is eligible before taking up your time explaining the study in detail to you. Is that okay?

1. What is your child's birthdate? _____

2. What is your child's sex? _____

3. Where did you hear about our project? _____

4. I'm going to list a number of diseases, and want you to tell me yes if your child has that problem, and no if he or she does not.

migraines	_____
epilepsy or other seizure disorder	_____
brain tumor	_____
head injuries	_____
spina bifida	_____
diabetes	_____
attention-deficit disorder	_____
conduct disorder	_____
oppositional defiant disorder	_____
behavior problems	_____
dyslexia	_____
learning disability	_____
mental retardation	_____

If the parent says "Yes" to dyslexia or learning disability, turn to the last page.

Does he or she have any significant health problems which I haven't asked about? What are they?

_____

_____

Is s/he gifted? _____

5. If the child does not meet one of the screening criteria, say "I'm afraid your child won't be able to participate because we need children _____ _____ (describe criteria that was not met). We very much appreciate your time and your interest."

6. If the child meets all of the screening criteria, say:

   Your child has met all of our preliminary criteria. Let me tell you about our study. We are trying to gather information that will help us help children who have brain disorders. We want to gather information about several tests to see how useful they are in evaluating children with brain problems. In order to see how useful these tests are with children with brain problems, we need a group of normal children to compare them with. Your child would be in this group. If you want him/her to participate, he/she will spend about an hour being asked some questions, and being asked to draw or put together some things. Most children find many of these tests fun to do. When he/she is done, we will tell him/her what a great job he/she did, and will allow him/her to select a sticker or small toy. We are paying $4 for each child's participation. You will have the option of our paying you, your child, or your church. Are you interested in the project?

   Answer the parent's questions. If they want to know what the tests are, say "They measure a wide variety of things -- some of the questions will be about things he or she may have learned in school, some tasks will look at his/her ability to draw or build things."

7. If the parent wants to participate, say "I have just a few more questions about some general family information to ask you, and then we can schedule an appointment."

   What is your marital status? _____
   How many years of school did you finish? _____

   What kind of work do you do? _____
   (if applicable) How many years of school did your spouse finish? _____
   (if applicable) What kind of work does your spouse do? _____
   What is your child's name? _____
   What is your child's race? _____

   Who do you want to get the $4 -- you, your child, or your church)? _____

8. Schedule an appointment.

Learning Disability Screening

1. Who diagnosed him/her with dyslexia/a learning disability?"

_____

2. "Do you have documentation of this diagnosis?" ___

If no, "We do need children who have dyslexia/ learning disabilities, but we need to make sure they have a learning disability through our criteria. If you can get us information about the diagnosis, your child would be a big help to our study. Do you think you can get us this information?" _____

If no, "Thank you very much for your time and for your interest in the project, but I'm afraid your child won't be able to participate because we won't be sure whether his/her dyslexia/learning disability meets the same criteria as the other children in our dyslexic/learning disabled group."

If yes, "Because of our interest in evaluating these tests' usefulness in evaluating children with learning disabilities, we are also interested in testing your child. If you can provide us with a copy of the documentation of the learning disability, we would like your child to participate. May I ask you a few more questions?" (Return to where you left off on page 1.)

REFERENCES

Ardila, A., Rosselli, M., & Rosas, P. (1989). Neuropsychological assessment in illiterates: Visuospatial and memory abilities. Brain and Cognition, 11, 147-166.

Bauer, R. M. (1993). Agnosia. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (3rd ed., pp. 165-214). New York: Oxford University Press.

Beery, K. E. (1989). The VMI, developmental Test of Visual-Motor Integration: Administration, scoring, and teaching manual (3rd ed.). Cleveland: Modern Curriculum Press.

Bennett-Levy, J. (1984). Determinants of performance on the Rey-Osterrieth Complex Figure Test: An analysis, and a new technique for single-case assessment. British Journal of Clinical Psychology, 23, 109-119.

Benton, A., & Tranel, D. (1993). Visuoperceptual, visuospatial, and visuoconstructive disorders. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (3rd ed., pp. 165-214). New York: Oxford University Press.

Benton, A. L., & Hamsher, K. deS. (1989). Multilingual Aphasia Exam: Manual of instructions (2nd ed.). Iowa City: AJA Associates.

Binder, L. M. (1982). Constructional strategies on complex figure drawings after unilateral brain damage. Journal of Clinical Neuropsychology, 4, 51-58.

Boyd, J. (1981). A validity study of the Hooper Visual Organization Test. Journal of Consulting and Clinical Psychology, 49, 15-19.

Boyd, J. (1982a). Reply to Rathburn and Smith: Who made the Hooper blooper? Journal of Consulting and Clinical Psychology, 50, 284-285.

Boyd, J. (1982b). Reply to Woodward. Journal of Consulting and Clinical Psychology, 50, 289-290.

Bradley, L. (1983). The organization of visual, phonological, and motor strategies in learning to read and spell. In U. Kirk (Ed.), Neuropsychology of language, reading, and spelling (pp. 235-254). New York: Academic Press.

Bryden, M. P., & Saxby, L. (1986). Developmental aspects of cerebral lateralization. In J. E. Obrzut & G. W. Hynd (Eds.), Child neuropsychology, volume 1: Theory and research (pp. 73-94). Orlando, FL: Academic Press, Inc..

Carpenter, M. B. (1991). Core text of neuroanatomy (4th ed.). Baltimore: Williams and Wilkins.

Carr, E. K., & Lincoln, N. B. (1988). Inter-rater reliability of the Rey figure copying test. British Journal of Clinical Psychology, 27, 267-268.

Casey, M. B., Winner, E., Hurwitz, I., & DaSilva, D. (1991). Does processing style affect recall of the Rey-Osterreith or Taylor complex figures? Journal of Clinical and Experimental Neuropsychology, 13, 600-606.

Cermak, S. (1985). Developmental dyspraxia. In E. A. Roy (Ed.), Neuropsychological studies of apraxia and related disorders (pp. 225-248). Amsterdam: Elsevier Science Publishers B. V..

Cohen, M., Town, P., & Buff, A. (1988). Neurodevelopmental differences in confrontational naming in children. Developmental Neuropsychology, 4, 75-81.

Cosden, M. (1985). Developmental Test of Visual-Motor Integration. In D. J. Keyser & R. C. Sweetland (Eds.), Test critiques (Vol. IV, pp. 229-237). Kansas City, MO: Test Corporation of America.

Denckla, M. B. (1994). Measurement of executive functions. In G. R. Lyon (Ed.), Frames of reference for the assessment of learning disabilities (pp. 118-142). Baltimore: Paul H. Brookes Publishing Co..

Dool, C. B., Stelmack, R. M., & Rourke, B. P. (1993). Event-related potentials in children with learning disabilities. Journal of Clinical Child Psychology, 22, 387-398.

Dunn, L. M. (1965). Expanded manual for the Peabody Picture Vocabulary Test. Circle Pines, MN: American Guidance Service.

Durrant, J. E. (1994). A decade of research on learning disabilities: A report card on the state of the literature. Journal of Learning Disabilities, 27, 25-33.

Eisenman, R., & Coyle, F. A. (1965). Absence of false positives on the Hooper Visual Organization Test. Psychological Reports, 17, 417-418.

Ellis, A. E., & Young, A. W. (1991). Human cognitive neuropsychology. East Sussex (U.K.): Lawrence Earlbaum Associates, Ltd., Publishers.

Fennell, R. S., Fennell, E. B., Carter, R. L., Mings, E. L., Klausner, A. B., & Hurst, J. R. (1992). Correlations between performance on neuropsychological tests in children with chronic renal failure. Child Nephrology and Urology, 10, 199-204.

Franzen, M. D. (1986). Multilingual Aphasia Examination. In D. J. Keyser and R. C. Sweetland (Eds.), Test critiques (Vol. V, pp. 278-282). Kansas City, MO: Test Corporation of America.

Friedman, R. B., Ween, J. E., & Albert, M. L. (1993). Alexia. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (3rd ed., pp. 37-62). New York: Oxford University Press.

Gerson, A. (1974). Validity and reliability of the Hooper Visual Organization Test. Perceptual and Motor Skills, 39, 95-100.

Gesell, A. L. (1977). The child from five to ten (Rev. ed.). New York: Harper & Row, Publishers.

Gesell, A. L., & Amatruda, C. S. (1974). Developmental diagnosis: The evaluation and management of normal and abnormal neuropsychologic development in infancy and early childhood (3rd ed.). Hagerstown, MD: Harper & Row, Publishers.

Goodgold-Edwards, S. A., & Cermak, S. A. (1989). Integrating motor control and motor learning concepts with neuropsychological perspectives on apraxia and developmental dyspraxia. American Journal of Occupational Therapy, 44, 431-439.

Gray, J. W., & Dean, R. S. (1985). Hooper Visual Organization Test. In D. J. Keyser & R. C. Sweetland (Eds.), Test critiques (Vol. III, pp. 340-343). Kansas City, MO: Test Corporation of America.

Halperin, J. M., Healy, J. M., Zeitschick, E., Ludman, W. L., & Weinstein, L. (1989). Developmental aspects of linguistic and mnestic abilities in normal children. Journal of Clinical and Experimental Neuropsychology, 11, 518-528.

Haxby, J. V., Grady, C. L., Horwitz, B., Ungerleider, L. G., Mishkin, M., Carson, R. E., Herscovitch, P., Schapiro, M. B., & Rapoport, S. I. (1991). Dissociation of object and spatial visual processing pathways in human extrastriate cortex. Proceedings of the National Academy of Science, USA, 88, 1621-1625.

Hayes, W. L. (1963). Statistics for psychologists. New York: Holt, Rinehart and Winston.

Haynes, J. P. (1982). Validity of a WISC-R short form with male delinquents. Journal of Clinical Psychology, 38, 406-408.

Heilman, K. M., Bowers, D., & Valenstein, E. (1993). Emotional disorders associated with neurological disorders. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (3rd ed., pp. 461-498). New York: Oxford University Press.

Heilman, K. M., & Rothi, L. J. G. (1993). Apraxia. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (3rd ed., pp. 141-164). New York: Oxford University Press.

Heilman, K. M., Watson, R. T., & Valenstein, E. (1993). Neglect and related disorders. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (3rd ed., pp. 279-336). New York: Oxford University Press.

Hilgert, L. D., & Treloar, J. H. (1985). The relationship of the Hooper Visual Organization Test to sex, age, and intelligence of elementary school children. Measurement and Evaluation in Counseling and Development, 17, 203-206.

Hollingshead, S. E. (1975). Four factor index of social status. New Haven, CT: S. E. Hollingshead.

Hooper, H. E. (1952). Use of the Hooper Visual Organization Test in the differentiation of organic brain pathology from normal, psychoneurotic, and schizophrenic reactions. American Psychologist, 7, 350.

Hooper, H. E. (1958). The Hooper Visual Organization Test. Los Angeles: Western Psychological Services.

Hooper Visual Organization Test (VOT) manual, 1983 edition (1983). Los Angeles: Western Psychological Services.

Hubel, D. H., & Wiesel, T. N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. Journal of Physiology, 160, 106-154.

Hubel, D. H. & Wiesel, T. N. (1970). The period of susceptibility to the physiological effects of unilateral eye closure in kittens. Journal of Physiology, 206, 419-436.

Hynd, G. W., & Semrud-Clikeman, M. (1989a). Dyslexia and brain morphology. Psychological Bulletin, 106, 447-482.

Hynd, G. W., & Semrud-Clikeman, M. (1989b). Dyslexia and neurodevelopmental pathology: Relationships to cognition, intelligence, and reading skill acquisition. Journal of Learning Disabilities, 22, 204-220.

Hynd, G. W., Semrud-Clikeman, M., Lorys, A. R., Novey, E. S., Eliopulos, D. (1990). Brain morphology in developmental dyslexia and attention deficit disorder/hyperactivity. Archives of Neurology, 47, 919-926.

Jackson, R. E., & Culbertson, W. C. (1977). The Elizur Test of psycho-organicity and the Hooper Visual Organization Test as measures of childhood neurological impairment. Journal of Clinical Psychology, 33, 213-214.

Kandel, E. R., Schwartz, J. H., & Jessell, T. M. (1991). Principles of neural science (3rd ed.). New York: Elsevier Science Publishing Co., Inc..

Kaplan, E. F., Goodglass, H., & Weintraub, S. (1978). The Boston Naming Test. Boston: E. Kaplan and H. Goodglass.

Karapetsas, A., & Kantas, A. (1991). Visuomotor organization in the child: A neuropsychological approach. Perceptual and Motor Skills, 72, 211-217.

Karapetsas, A., & Vlachos, F. (1992). Visuomotor integration in the left-handed child: A neuropsychological approach. Perceptual and Motor Skills, 75, 699-705.

King, M. C. (1981). Effects of non-focal brain dysfunction on visual memory. Journal of Clinical Psychology, 37, 638-643.

Kinsbourne, M. (1989). Mechanisms and development of hemisphere specialization in children. In C.R. Reynolds & E. Fletcher-Janzen (Eds.), Handbook of clinical child neuropsychology (pp. 17-40). New York: Plenum Press.

Kinsbourne, M., & Hiscock, M. (1981). Cerebral lateralization and cognitive development: Conceptual and methodological issues. In G. W. Hynd & J. E. Obrzut (Eds.), Neuropsychological assessment and the school-age child: Issues and procedures (pp. 125-166). New York: Grune & Stratton, Inc..

Kirk, U. (1992). Evidence for early acquisition of visual organization ability: A developmental study. The Clinical Neuropsychologist, 6, 171-177.

Kolb, B., & Fantie, B. (1989). Development of the child's brain and behavior. In C.R. Reynolds & E. Fletcher-Janzen (Eds.), Handbook of clinical child neuropsychology (pp. 17-40). New York: Plenum Press.

Kolb, B., & Whishaw, I. Q. (1990). Fundamentals of human neuropsychology (3rd ed.). New York: W. H. Freeman and Company.

Lamb, M. E., & Campos, J. J. (1982). Development in infancy: An introduction. New York: Random House, Inc..

Leonard, C. M., Voeller, K. K. S., Lombardino, L. J., Morris, M. K., Hynd, G. W., Alexander, A. W., Andersen, H. G., Garofalakis, M., Honeyman, J. C., Mao, J., Agee, F., & Staab, E. V. (1993). Anomalous cerebral structure in dyslexia revealed with magnetic resonance imaging. Archives of Neurology, 50, 461-469.

Levin, H. S., Goldstein, F. C., & Spiers, P. A. (1993). Acalculia. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (3rd ed., pp. 91-122). New York: Oxford University Press.

Lezak, M. D. (1983). Neuropsychological assessment (2nd ed.). New York: Oxford University Press.

Little, S. S. (1993). Nonverbal learning disabilities and socioemotional functioning: A review of recent literature. Journal of Learning Disabilities, 26, 653-665.

Love, H. G. I. (1970). Validation of the Hooper Visual Organization Test on a New Zealand psychiatric hospital population. Psychological Reports, 27, 915-917.

McCarthy, R. A., & Warrington, E. K. (1990). Cognitive neuropsychology: A clinical introduction. San Diego: Academic Press, Inc.

McIntosh, A. R., Grady, C. L., Ungerleider, L. G., Haxby, J. V., Rapoport, S. I., & Horwitz, B. (1994). Network analysis of cortical visual pathways mapped with PET. The Journal of Neuroscience, 14, 655-666.

Melamed, L. E., & Melamed, E. C. (1985). Neuropsychology of perception. In L. C. Hartlage & C. F. Telzrow (Eds.), The neuropsychology of individual differences: A developmental perspective (pp. 61-91). New York: Plenum Press.

Menkes, J. H., Till, K., & Gabriel, R. S. (1990). Malformations of the central nervous system. In J. H. Menkes (Ed.), Textbook of child neurology (4th ed., pp. 209-283). Philadelphia: Lea & Febiger.

Messerli, P., Seron, X., & Tissot, R. (1979). Quelques aspects des troubles de la programmation dans le syndrome frontal. Archives Suisse de Neurologie, Neurochirurgie et de Psychiatrie, 125, 23-35.

Miller, M., & Rohr, M. E. (1980). Verbal mediation for perceptual deficits in learning disabilities: A review and suggestions. Journal of Learning Disabilities, 13, 33-35.

Mings, E. L. (1987). Visual-motor integration deficits in pediatric renal disease. Gainesville, FL: Mings.

Morris, M. K. (1991). Cognitive neuropsychological mechanisms of reading in children. Paper presented at the Orton Dyslexia Society, Florida Branch Spring Meeting, Orlando, FL.

Morris, R. D. (1988). Classification of learning disabilities: Old problems and new approaches. Journal of Consulting and Clinical Psychology, 56, 789-794.

Murray, E. A., Cermak, S. A., O'Brien, V. (1990). The relationship between form and space perception, constructional abilities, and clumsiness in children. The American Journal of Occupational Therapy, 44, 623-628.

Nakamura, R. K., & Mishkin, M. (1986). Chronic 'blindness' following lesions of nonvisual cortex in the monkey. Experimental Brain Research, 63, 173-184.

Nakamura, R. K., Schein, S. J., & Desimone, R. (1986). Visual responses from cells in striate cortex of monkeys rendered chronically 'blind' by lesions of nonvisual cortex. Experimental Brain Research, 63, 185-190.

Nieuwenhuys, R., Voogd, J., & van Huijzen, C. (1988). The human central nervous system: A Synopsis and atlas (3rd Ed.). Berlin: Springer-Verlag.

Ornstein, R., Johnstone, J., Herron, J., & Swencionis, C. (1980). Differential right hemisphere engagement in visuospatial tasks. Neuropsychologia, 18, 49-64.

Osterrieth, (1944). Le teste de copie d'une figure complexe. Archives de Psychologie, 30, 206-356.

Piaget, J. (1977). The construction of reality in the child. In H. E. Gruber & J. J. Voneche (Eds. and Trans.), The essential Piaget (pp. 250-294). New York: Basic Books, Inc., Publishers. (Original work published 1937).

Piaget, J. (1977). The first year of life of the child. In H. E. Gruber & J. J. Voneche (Eds. and Trans.), The essential Piaget (pp. 198-214). New York: Basic Books, Inc., Publishers. (Original work published 1927).

Piaget, J. (1977). The origins of intelligence in children. In H. E. Gruber & J. J. Voneche (Eds. and Trans.), The essential Piaget (pp. 215-249). New York: Basic Books, Inc., Publishers. (Original work published 1936).

Piaget, J., & Inhelder, B. (1969). The psychology of the child (H. Weaver, Trans.). New York: Basic Books, Inc.. (Original work published 1966.)

Pillon, B. (1981). Troubles visuo-constructifs et methodes de compensation: Resultats de 85 patients atteints de lesions cerebrales. Neuropsychologia, 19, 375-383.

Rathburn, J., & Smith, A. (1982). Comment on the validity of Boyd's validation study of the Hooper Visual Organization Test. Journal of Consulting and Clinical Psychology, 50, 281-283.

Rey, A. (1941). L'examen psychologique dans le cas d'encephalopathie traumatique. Archives de Psychologie, 28, 286-340.

Roeltgen, D. (1993). Agraphia. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (3rd ed., pp. 66-90). New York: Oxford University Press.

Rourke, B. P. (1975). Brain-behavior relationships in children with learning disabilities: A research program. American Psychologist, 30, 911-920.

Rourke, B. P. (1989). Nonverbal learning disabilities: The syndrome and the model. New York: The Guilford Press.

Rourke, B. P. (1993). Arithmetic disabilities, specific and otherwise: A neuropsychological perspective. Journal of Learning Disabilities, 26, 214-226.

Rourke, B. P. (1994). Neuropsychological assessment of children with learning disabilities: Measurement issues. In G. R. Lyon (Ed.), Frames of reference for the assessment of learning disabilities (pp. 475-514). Baltimore: Paul H. Brookes Publishing Co..

Ryan, J. J. (1981). Clinical utility of a WISC-R short form. Journal of Clinical Psychology, 37, 389-391.

Sattler, J. M. (1988). Assessment of children (3rd ed.). San Diego: Jerome M. Sattler, Publisher.

Seidel, W. T. (1994). Applicability of the Hooper Visual Organization Test to pediatric populations: Preliminary findings. The Clinical Neuropsychologist, 8, 59-68.

Shaywitz, S. E., Shaywitz, B. A., Fletcher, J. M., & Escobar, M. D. (1990). Prevalence of reading disability in boys and girls: Results of the Connecticut Longitudinal Study. Journal of the American Medical Association, 264, 998-1002.

Snell, R. S. (1992). Clinical neuroanatomy for medical students (3rd ed.). Boston: Little, Brown and Company.

Spreen, O., Tupper, D., Risser, A., Tuokko, H., & Edgell, D. (1984). Human developmental neuropsychology. New York: Oxford University Press.

Sterne, D. M. (1973). The Hooper Visual Organization Test and the Trail Making Tests as discriminants of brain injury. Journal of Clinical Psychology, 29, 212-213.

Tabachnick, B. G., & Fidell, L. S. (1989). Using multivariate statistics (2nd ed.). Cambridge, MA: Harper & Row, Publishers, Inc..

Tamkin, A. S., & Hyer, L. A. (1984). Testing for cognitive dysfunction in the aging psychiatric population. Military Medicine, 149, 397-399.

Tamkin, A. S., & Jacobsen, R. (1984). Age-related norms for the Hooper Visual Organization Test. Journal of Clinical Psychology, 40, 1459-1463.

Tamkin, A. S., & Kunce, J. T. (1985). A comparison of three neuropsychological tests: The Weigl, Hooper, and Benton. Journal of Clinical Psychology, 41, 660-664.

Taylor, H. G. (1988a). Learning disabilities. In E. J. Mash & L. G. Terdal (Eds.), Behavioral assessment of childhood disorders (2nd ed., pp. 402-450). New York: Guilford Press.

Taylor, H. G. (1988b). Neuropsychological testing: Relevance for assessing children's learning disabilities. Journal of Consulting and Clinical Psychology, 56, 795-800.

Taylor, H. G., & Schatschneider, C. (1992). Child neuropsychological assessment: A test of basic assumptions. The Clinical Neuropsychologist, 6, 259-275.

Thorndike, R. M. (1978). Correlational procedures for research. New York: Gardner Press, Inc.

Tranel, D. (1992). Functional neuroanatomy: Neuropsychological correlates of cortical and subcortical damage. In The American Psychiatric Press textbook of neuropsychiatry (pp. 57-88). Washington, DC: New York Psychiatric Press.

Vellutino, F. R., Scanlon, D. M., & Tanzman, M. S. (1994). Components of reading ability: Issues and problems in operationalizing word identification, phonological coding, and orthographic coding. In G. R. Lyon (Ed.), Frames of reference for the assessment of learning disabilities (pp. 279-329). Baltimore: Paul H. Brookes Publishing Co.

Vernon, P. A. (1984). Wechsler Intelligence Scale for Children-Revised. In D. J. Keyser & R. C. Sweetland, Test critiques (Vol. I, pp. 740-749). Kansas City, MO: Test Corporation of America.

Visser, R. S. H. (1973). Manual of the Complex Figure Test. Amsterdam: Swets and Zeitlinger B. V..

Voeller, K. K. S. (1991). Social-emotional learning disabilities. Psychiatric Annals, 21, 735-741.

Vogel, S. A. (1990). Gender differences in intelligence, language, visual-motor abilities, and academic achievement in students with learning disabilities: A review of the literature. Journal of Learning Disabilities, 23, 44-52.

Waber, D. P., & Bernstein, J. H. (1994, February 2-5). Performance of normal and learning disabled children on the Rey-Osterrieth Complex Figure test (ROCF): Validation of the Waber-Holmes developmental scoring procedure. Paper presented at the twenty-second annual meeting of the International Neuropsychological Society, Cincinnati, OH.

Waber, D. P., & Holmes, J. M. (1985). Assessing children's copy productions of the Rey-Osterrieth Complex Figure. Journal of Clinical and Experimental Neuropsychology, 7, 264-280.

Waber, D. P., & Holmes, J. M. (1986). Assessing children's memory productions of the Rey-Osterrieth Complex Figure. Journal of Clinical and Experimental Neuropsychology, 8, 563-580.

Walker, R. G. (1956). The revised Hooper Visual Organization Test as a measure of brain damage. Journal of Clinical Psychology, 12, 387-388.

Walker, R. G. (1957). Schizophrenia and cortical involvement. Journal of Nervous and Mental Disease, 125, 226-228.

Wang, P. L. (1977). Visual organization in brain-damaged adults. Perceptual and Motor Skills, 45, 723-728.

Wechsler, D. (1945). A standardized memory scale for clinical use. Journal of Psychology, 19, 87-95.

Wechsler, D. (1974). Manual for the Wechsler Intelligence Scale for Children-Revised. New York: The Psychological Corporation.

Wechsler, D. (1989). Manual for the Wechsler Preschool and Primary Scale of Intelligence-Revised. San Antonio: The Psychological Corporation.

Wechsler, D. (1991). WISC-III: Wechsler Intelligence Scale for Children-Third edition manual. San Antonio: The Psychological Corporation.

Wiesel, T. N., & Hubel, D. H. (1965). Extent of recovery from the effects of visual deprivation in kittens. Journal of Neurophysiology, 28, 1029-1040.

Wentworth-Rohr, I., Mackintosh, R. M., & Fialkoff, B. S. (1974). The relationship of Hooper VOT score to sex, education, intelligence, and age. Journal of Clinical Psychology, 30, 73-75.

Williams, H. G. (1983). Perceptual and motor development. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Willis, W. G., & Widerstrom, A. H. (1986). Structure and function in prenatal and postnatal neuropsychological development: A dynamic interaction. In J. E. Obrzut & G. W. Hynd (Eds.), Child neuropsychology, volume 1: Theory and research (pp. 13-53). Orlando, FL: Academic Press, Inc..

Wolf, M., & Obregon, M. (1992). Early naming deficits, developmental dyslexia, and a specific deficit hypothesis. Brain and Language, 42, 219-247.

Woods, B. T. (1980). The restricted effects of right-hemisphere lesions after age one: Wechsler test data. Neuropsychologia, 18, 65-70.

Woodward, C. A. (1982). The Hooper Visual Organization Test: A case against its use in neuropsychological assessment. Journal of Consulting and Clinical Psychology, 50, 286-288.

Yeates, K. O. (1994). Comparison of developmental norms for the Boston Naming Test. The Clinical Neuropsychologist, 8, 91-98.

Young, A. W. (1983). The development of right hemisphere abilities. In A. W. Young (Ed.), Functions of the right cerebral hemisphere (pp. 147-169). New York: Academic Press.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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